



AGRICULTURAL RESEARCH INSTITUTE

PUSA

PROCEEDINGS
of the
American Society
for
Horticultural Science
for
1931

64863



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Volume 28

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TWENTY-EIGHTH ANNUAL MEETING



T. H. McHATTON

PROCEEDINGS
OF THE
AMERICAN SOCIETY
FOR
HORTICULTURAL SCIENCE
FOR
1931

Twenty-Eight Annual Meeting
New Orleans, Louisiana
December 28, 29, and 30, 1931

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CONTENTS

	Page
Officers and Committees for 1932	ix
Constitution and By-Laws	x
Society Affairs	xi
Resumé of the Annual Meeting	xi
Report of Various Committees	xi
Election of Officers	xi
Report of the Executive Committee	xii
Resolutions	xiii
Treasurer's Report for 1931	xiv
Some Relationships Between Tree Response and Internal Composition of Shoots of the Peach, by F. P. Cullinan	1
Preliminary Report on Relation of Soil Moisture and Leaf Area to Fruit Development of the Georgia Belle Peach, by Ivan D. Jones	6
The Relation of Leaf Area per Peach to Physical Properties and Chemical Composition, by E. L. Overholser and L. L. Claypool	15
The Relation of Leaf Area to Size and Quality of Peaches, by J. H. Wein- berger	18
Some Fruiting Responses of the Peach to Applications of Nitrate of Soda, by Richard V. Lott	23
Some Vegetative Responses of the Peach to Applications of Nitrate of Soda, by T. E. Ashley	28
Preliminary Report of Effects of Time and Rate of Nitrate Fertilization on Growth and Yield of Elberta Peaches, by J. H. Beaumont and C. F. Wil- liams	34
Season Variations in Nitrogen Concentration in Twigs of Peach Trees under Sandhill Conditions, by C. F. Williams	39
Recent Developments in Citrus Coloring, by J. R. Winston and J. M. Lutz ..	45
Light and Pigment Development in Apples, by L. R. Streeter and G. W. Pearce	49
Effect of Selection within Apogamic and Clonal Progenies, by H. J. Webber ..	53
The Economic Importance of Apogamy in Citrus and Mangifera, by H. J. Webber	57
Hybridity in the Genus Liliun, by David Griffiths	62
Sweet Cherry Pollination in Washington for 1931, by L. L. Claypool, F. L. Overley and E. L. Overholser	67
Pollination Studies with Some Newer Apple Varieties, by H. E. Knowlton ..	71
Pollination of Certain Apple Bud Sports in North Central Washington, by E. L. Overholser and F. L. Overley	74
Pollination of the McIntosh Apple in the Champlain Valley—Third Progress Report, by A. B. Burrell and R. G. Parker	78
A Device to Facilitate Pollen Distribution by Bees, by A. B. Burrell and Geo. E. King	85
Further Observations on Factors Affecting Fruit Setting of the McIntosh Apple in New Hampshire, by L. P. Latimer	87
Apple Breeding: Statistical Analysis of Apple Breeding Material, by S. W. Edgecombe and H. L. Lantz	93
Fruit Breeding: A Method of Recording and Analyzing Data, by H. L. Lantz ..	97
The Persistence of Winter Injury in Certain Delicious Hybrids, by H. E. Nichols and H. L. Lantz	103
The Best Parents in Strawberry Breeding, by G. L. Slate	107
Self-Unfruitfulness in Prunus Tomentosa, by G. L. Slate	112
Chromosome Behavior as a Factor in Berry Breeding, by S. H. Yarnell	114

Self and Cross Fertility of Red Raspberry Varieties, by Max B. Hardy....	118
Red Raspberry Pollination Technique, by Max B. Hardy.....	122
A Preliminary Report on the Breeding of Vinifera Grape Varieties, by Elmer Snyder.....	125
Growth of Concord Grape Cuttings in Relation to Vigor, Chemical Composition and Relative Position on the Cane, by V. C. Calma and H. W. Richey.....	131
Further Studies on the Effect of Fruiting on the Shoot Growth of the Concord Grape, by A. L. Schrader.....	137
Effects of Pruning on Fruiting of Shoots and the Growth of Their Terminals and Laterals in the Concord, by A. S. Colby and L. R. Tucker (<i>abstract</i>)...	143
The Influence of Long Pruning and Thinning upon the Quality of Concord Grapes, by Newton L. Partridge.....	144
The Effect of Fruit Production and Fertilizer Treatments on the Maturity of Concord Grapes, by Newton L. Partridge.....	147
Irrigation Experiments with Grapes, by A. H. Hendrickson and F. J. Veihmeyer.....	151
Anatomical Differences in Pecan Varieties that Fruit Differently, by A. H. Finch.....	158
Endosperm and Embryo Development as Related to Filling of Pecans and Walnuts, by D. V. Shuhart.....	161
Some Characteristics of Pecan Varieties as Determined by Cracking Test, by M. E. Gardner and J. H. Beaumont.....	164
Performance Records of Pecan Varieties in North Carolina, by J. H. Beaumont, M. E. Gardner and Robert Schmidt.....	167
Strawberry Culture in Louisiana, by B. Szymoniak.....	173
Studies on the Effect of Chemical Fertilizers Upon Growth and Fruit Production of the Black Raspberry, by W. F. Cherry.....	176
Notes on the Fall Flowering Habit of the Red Raspberry, by W. G. Brierley..	180
Growth Studies in the Latham Raspberry, by W. G. Brierley.....	182
Transpiration in New and Old Canes of the Latham Raspberry, by W. G. Brierley.....	188
Seed and Berry Size of Cane Fruits, by G. M. Darrow and Hugh Sherwood...	194
Use of the Survey Method in Showing Cultural Factors in Red Raspberry Production, by John T. Bregger.....	200
Effect of Age of Plant on Flower Production and Yield of Strawberries in North Carolina, by E. B. Morrow and J. H. Beaumont.....	206
Length of the Fruit Development Period of Strawberry Varieties, by J. Harold Clark.....	211
Fruit Bud Differentiation in the Dunlap Strawberry in Relation to the Age and Position of the Plant, by J. C. Schilleter.....	216
The Relation of Fertilizers to Respiration and Certain Physical Properties of Strawberries, by E. L. Overholser and L. L. Claypool.....	220
The Effect of Fertilizer on the Quality and on the Keeping and Carrying Qualities of Strawberries, by W. D. Kimbrough (<i>abstract</i>).....	224
Transpiration Studies on Strawberries, by Geo. M. Darrow and Hugh Sherwood.....	225
Effect of Fertilizers on Firmness and Flavor of Strawberries in North Carolina, by Geo. M. Darrow.....	231
The Effect of Fertilizers on the Handling Qualities and Chemical Analyses of Strawberries and Tomatoes, by George W. Cochran and J. E. Webster.....	236
Respiration Studies with Lettuce, by K. A. McKenzie.....	244
Some Effects of Irrigation upon Yield and Quality of Potatoes Produced in the Yakima Valley, by L. L. Claypool and O. M. Morris.....	249
Some Responses of Potato Plants to Spacing and Thinning, by L. L. Claypool and O. M. Morris.....	253

Effect of Fertilizer Treatment on the Yield, Quality, and Keeping Qualities of Irish Potatoes, by W. D. Kimbrough (<i>abstract</i>).....	256
A Late Crop of Potatoes for Oklahoma, by George W. Cochran.....	257
The Relation of Solar and Sky Radiation Temperature, and Humidity to the Sun-scaud of Potatoes in 1931, by Walter M. Peacock, R. C. Wright, and T. M. Whiteman.....	261
The Healing of Potatoes Skinned During Harvest as Affected by Temperature, Humidity and Solar and Sky Radiation, by Walter M. Peacock.....	266
Proximal Dominance in the Sweet Potato, by Ross C. Thompson and J. H. Beattie.....	270
A Comparison of the Freezing and Alcohol Method in the Preservation of Sweet Potato Samples for Sugar Determinations, by N. D. Morgan.....	276
A Study of Growth and Development of the Potato Plant, by Ora Smith.....	279
Effects of Light and Temperature on the Growth and Tuberization of Potato Seedlings, by J. H. Beaumont and J. G. Weaver.....	285
Size of Seed Piece and Sprout Removal in Relation to Sprout Formation on Jerusalem Artichoke Tubers, by Victor R. Boswell.....	291
Length of Rest Period of the Tuber of Jerusalem Artichoke (<i>Helianthus tuberosus</i> L.), by Victor R. Boswell.....	297
Apical Dominance in the Tuber of the Jerusalem Artichoke (<i>Helianthus tuberosus</i> L.) by Victor R. Boswell.....	301
Results of Paper Mulch Experiments with Vegetable Crops, by H. C. Thompson and Hans Platenius.....	305
Correlation Studies Between Size of Crown and Yields of Asparagus, by E. S. Haber (<i>abstract</i>).....	308
The Effect of Length of Cutting Season on Yields of Asparagus, by E. S. Haber (<i>abstract</i>).....	309
Anthesis and Pollination of the Capsicums, by A. T. Erwin (<i>abstract</i>).....	309
Carrot Seed Germination, by H. A. Borthwick.....	310
Some Factors Influencing the Reproduction of Shallots, by J. M. Jenkins, Jr. and Julian C. Miller.....	315
The Carbohydrate and Nitrogen Metabolism in Celery as Related to Premature Seeding, by H. Platenius (<i>abstract</i>).....	317
Some Factors Affecting the Color and Thickness of Onion Scales, by J. E. Knott.....	318
Premature Seedstalk Formation in Table Beets (Preliminary Report) by Emil Chroboczek....	323
Self-Sterility and Fertility in Garden Beets as Indicated by Seed Production under Paper Bags, by Roy Magruder.....	328
The Successful Pollination Period of Garden Beets, <i>Beta vulgaris</i> by Roy Magruder.....	332
Some Effects of Wounding Onion Bulbs on Seed Production, by A. L. Wilson.....	336
A New Method of Growing Cabbage Seed, by Julian C. Miller.....	341
Effect of Ringing on Growth and Fruiting in the Tomato, by C. E. Steinbauer.....	343
A Study of the Regions of the Tomato Fruit as Affected by Selection, by E. C. Stair and J. H. MacGillivray.....	350
Tomato Color as Affected by Processing Temperatures, by John H. MacGillivray.....	353
Influence of Inbreeding Upon the Season of Maturity in Cabbage, by O. H. Pearson.....	359
Thresher Injury in Baby Lima Beans, by H. A. Borthwick (<i>abstract</i>).....	366
Some Chemical and Physical Changes Observed in Green Lima Beans Subjected to Various Storage Conditions, by R. L. Carolus.....	367
Experiments with Ultra-Violet Transmitting Glasses for Growing Vegetable Plants in Coldframes, by Victor R. Boswell and A. M. Jackson.....	375

Studies of the Hardiness of Plants: A Modification of the Newton Pressure Method, for Small Samples, by S. T. Dexter (<i>abstract</i>).....	380
Reducing the Day Length of Chrysanthemums for the Production of Early Blooms by the Use of Black Sateen Cloth, by Kenneth Post.....	382
Studies of Photoperiodism of the Chrysanthemum, by G. H. Poesch.	389
Vegetative Growth and Flower Production of Summer Annuals When Grown under Cheese Cloth, by Kenneth Post.....	393
The Effect on Gladioli of Heating the Soil with Electricity, by J. R. Tavernetti and S. L. Emsweller.....	398
Forcing Plants with Artificial Light, by G. H. Poesch.....	402
Flower Bud Differentiation in the Gladiolus, by John V. Watkins.....	407
Factors Influencing the Flower Color of Hydrangeas, by Raymond C. Allen	410
The Effect of Steaming the Soil on Yields of Carnations, by S. W. Decker..	413
The Growth of Several Floricultural Crops on Limed and Acidified Soils, by F. F. Weinard and S. W. Decker.....	416
Summer Flowering Phloxes, by A. M. S. Pridham.....	418
Peony Fertilizers and Cutting Methods, by S. W. Decker and F. F. Weinard..	423
The Use of Washed Sand as a Substitute for Soil in Greenhouse Culture, by Alex Laurie.....	427
Effects of the Application of Nutrients to Ornamental Trees, by A. F. DeWerth and L. C. Chadwick.....	432
Growth Experiments with Shade Trees under Lawn Conditions, by Donald Wyman.....	435
Effect of Temperature and Dessication During Storage on Germination of Seeds of the American Elm (<i>Ulmus americana</i> L.) by C. E. Steinbauer and G. P. Steinbauer.....	441
A Study of the Broad-leaf Evergreens of the Southeastern States, by Jesse A. DeFrance.....	444
Rooting Response of Conifers to Treatments with Organic and Inorganic Compounds, by Irwin Klein.....	447
Studies in Propagation of Softwood Cuttings of Ornamentals Based on Temperature, Defoliation and Kind of Media, by H. C. Esper and L. R. Roof..	452
Factors Influencing the Rooting of Deciduous Hardwood Cuttings, By L. C. Chadwick.....	455
Experiences in Rooting Soft and Hardwood Cuttings of Hardy Fruits, by H. B. Tukey and Karl Brase.....	460
Vegetative Propagation of Deciduous Fruits, by W. L. Howard.....	465
Notes Upon Stock and Scion Relations in 1931, by R. H. Roberts.....	470
Influence of Size of Mahaleb Seedlings on Nursery Grades, by C. L. Burkholder and Laurenz Greene.....	473
A Comparison of the Variability in Growth of Several Varieties of Apple Trees Growing on Seedling Roots and Upon their Own Roots, by F. S. Lagasse...	475
A Study of Growth of Pear Inarches, by L. D. Davis and W. P. Tufts.....	485
The Effect of Paraffining, Pruning, and Other Storage Treatments Upon the Growth of Roses and Cherry Trees, by H. B. Tukey and Karl Brase.....	489
An Apparatus for Spraying Plants with Melted Paraffin or Other Waxes, by T. J. Maney.....	496
Some Comparisons of Methods of Grafting Evergreens, by V. T. Stoutemyer.	498
The Effect of Nitrate Applications on the Soluble Carbohydrates in Apples (Second Report), by E. F. Hopkins and E. W. Greve.....	501
Some Effects of Preservation by Freezing on Quality of Fruits and Vegetables, by J. G. Woodroof (<i>abstract</i>).....	507
A Survey of Residua from Phosphorus Applications on Orchard Soils, by R. M. Smock and J. H. Gourley.....	509
Sampling Orchard Soils for Nitrate Determinations, by George A. Filingr...	515

Carbohydrate and Nitrogen Relationships in Apple Shoots as Influenced by Soil Management, by J. T. Sullivan and F. P. Cullinan.....	519
The Nitrogen Supply for Young Apple Trees Growing in Leguminous and Non-Leguminous Sod, by A. J. Heinicke.....	526
Nitrogen Intake and Translocation in Apple Trees Following Fall, Winter and Spring Sodium Nitrate Applications, by W. W. Aldrich.....	532
Growth of Fruit and Stomatal Behavior of Elberta Peaches as Affected by Weather Conditions, by H. J. Weinberger.....	539
The Relation of Soil Moisture and Spray Applications to Stomatal Behavior and Growth of Jonathan Apples, by F. L. Overley, E. L. Overholser and I. A. Haut.....	543
Relation of Moisture Supply to Stomatal Behavior of the Apple, by J. S. Furr and E. S. Degman.....	547
Light Intensity as a Factor in the Development of Apple Color and Size, by A. L. Schrader and P. C. Marth.....	552
Little-leaf or Rosette in Fruit Trees, by W. H. Chandler, D. R. Hoagland, and P. L. Hibbard.....	556
A Starch-Splitting Enzyme in Apple Tissues, by C. P. Harley, D. F. Fisher and M. P. Masure.....	561
Comparative Temperature of Apples, by Arthur Meyer.....	566
Cold Storage Tests with McIntosh under Forced Air Circulation, by E. J. Rasmussen.....	568
Some Effects of Fertilizer upon Storage Response of Jonathan Apples, by F. L. Overley and E. L. Overholser.....	572
Orchard Variability in Maturing the Italian Prune, by Lowell R. Tucker....	578
The Respiration of Some Fruits in Relation to Temperature, by M. H. Haller, P. L. Harding, J. M. Lutz and D. H. Rose.....	583
Studies in the Transpiration Rate of Apple Varieties, by Oscar J. Dowd.....	590
Standard Rainfall, by Paul Tabor.....	594
Effect of Fruit Thinning upon Carbohydrate Accumulation, Formation of Fruit Buds and Set of Bloom in Apple Trees, by W. W. Aldrich.....	599
Effect of Thinning before the June Drop upon Fruit Production by F. S. Howlett.....	605
Results of Some Experiments in Pruning Young Apple Trees, by T. J. Talbert.....	610
Tabular Biometrical Presentation of Pruning Treatments with Apple Trees, by Fred W. Hofmann.....	613
A Comparison of Different Methods of Taking Samples of Apples in Experimental Plots, by M. J. Dorsey and R. L. McMunn.....	619
Variations in Shape of Bartlett Pears, by W. P. Tufts and C. J. Hansen....	627
Black-end and its Occurrence in Selected Pear Orchards, by L. D. Davis and W. P. Tufts.....	634
Maturity and Rate of Ripening of Gravenstein Apples in Relation to Bitter Pit Development, by F. W. Allen.....	639
Notes on the 1930 Drought in West Virginia Orchards, by Leif Verner.....	646
Lowering Apple Orchard Cover Crop Costs, by Fred W. Hofmann.....	654
Some Changes in the Homemade Paddle Apple Washer, by Fred W. Hofmann.....	655
The Effects of Humidity and Temperature Upon the Wetting of Peach Shoots, by W. A. Ruth and G. V. Falkenberg.....	657
Summer Oil Sprays for Late Brood Codling-Moth, by H. G. Swartwout....	663
The Evolution of the Horticulturist, by T. H. McHatton.....	667
Obituary	
Walter Leon Cutler.....	676
Membership Roll for 1931.....	677
Index.....	685

OFFICERS AND COMMITTEES FOR 1932

<i>President</i>	H. A. JONES
<i>Vice-President</i>	J. R. MAGNESS
<i>Secretary-Treasurer</i>	H. B. TUKEY
<i>Assistant Secretary</i>	J. H. CLARK

EXECUTIVE COMMITTEE

T. H. MCHATTON, <i>Chairman</i>	H. A. JONES, <i>President, ex-officio</i>
E. F. PALMER	H. B. TUKEY, <i>Secretary, ex-officio</i>
V. R. BOSWELL	

PROGRAM COMMITTEE

F. P. CULLINAN, <i>Chairman</i>	L. H. MCDANIELS	H. B. TUKEY
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NOMINATING COMMITTEE

J. W. BUSHNELL, <i>Chairman</i>	V. R. GARDNER
S. H. YARNELL	J. H. BEAUMONT
W. H. UPSHALL	

SECTIONAL GROUPS AND MEMBERSHIP

J. H. WARING, <i>Chairman</i>	R. A. MCGINTY	W. P. TUFTS
J. C. MILLER	W. G. BRIERLEY	W. R. LESLIE

BOTANICAL AND BIOLOGICAL ABSTRACTS

F. C. BRADFORD	J. W. BUSHNELL
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A. A. A. S. COUNCIL

W. H. ALDERMAN	J. R. MAGNESS
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NATIONAL RESEARCH COUNCIL

E. C. AUCHTER

EDITORIAL COMMITTEE

F. C. BRADFORD (1936)	J. R. MAGNESS (1933)
V. R. BOSWELL (1932)	J. H. GOURLEY (1934)
G. T. NIGHTINGALE (1935)	

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Any person who has a baccalaureate degree and holds an official position in an agricultural college, experiment station, or Federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, and a Secretary-Treasurer, who, together with the chairman of the standing committees, shall constitute a Council to act upon all applications for membership. There shall also be an Assistant Secretary. These officers shall be elected annually by ballot.

ARTICLE VI

This Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting.

SEC. 2. There shall be a Committee on Nominations consisting of five (5) members, who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this committee, at the following meeting, to suggest to the Society nominees for the various committees, and one nominee for each of the offices for the ensuing year.

SEC. 3. There shall be an Executive Committee, consisting of three (3) members and the President and the Secretary, ex-officio. This committee shall perform the usual duties devolving upon such committee.

SEC. 4. The Committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them and to report the present status of the same.

SEC. 5. There shall be a Committee on Program, consisting of three (3) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

SEC. 6. The annual dues of the Society shall be four dollars.

SEC. 7. Ten members of the Society shall constitute a quorum.

*The Constitution and By-Laws as amended from time to time.

SOCIETY AFFAIRS

RESUMÉ OF THE ANNUAL MEETING AT NEW ORLEANS, LOUISIANA, DECEMBER 28, 29, AND 30, 1931.

The twenty-eighth annual meeting was highly successful in both terms of attendance and papers contributed. There were 55 present at the opening session. The highest attendance at any one session was in the neighborhood of 100, with the exception of the joint session with the American Society of Plant Physiologists, when more than 150 were present. It was necessary this year to organize thirteen sections, beside an evening round table for extension workers, and an evening devoted to the banquet and social good time. The sessions were held at the St. Charles Hotel, which was also the Society headquarters, adding greatly to the convenience of the members.

On one afternoon there were four sections operating at the same time. Yet even with so many papers presented, namely, 156, the meetings were run promptly according to schedule. This was due in large part to the response of authors to personal letters requesting them to summarize their papers and to be prepared to present their material clearly with the aid of charts, lantern slides, and prepared materials. Papers were grouped according to subject, and a brief discussion period allowed at the completion of each group.

The next meeting will be held at Atlantic City, New Jersey, December 28, 29, and 30, 1932.

DINNER AND SOCIAL EVENING

The dinner and social evening was held at the St. Charles Hotel with 100 in attendance. Splendid arrangements were made by Dr. Julian C. Miller. Flowers were provided by Louisiana State University, and souvenirs from Louisiana were presented as favors. The President's address was the main feature of the dinner, following which with Dr. M. J. Dorsey as toastmaster, there were brief talks by Dr. H. J. Webber, Dr. W. L. Howard, Dr. W. H. Chandler and Dr. E. C. Auchter.

REPORT OF REPRESENTATIVE ON THE NATIONAL RESEARCH COUNCIL

Dr. E. C. Auchter, Society representative on the National Research Council, reported that two workers in horticulture had secured grants through the Council. He explained the routine involved in making application and pointed out the opportunities available for securing financial support for individual research work by grants from the National Research Council and from other agencies.

ELECTION OF OFFICERS

In its report the nominating committee submitted the names of H. A. Jones and Laurenz Greene to ballot upon for the nomination of president. The ballot resulted in the nomination of H. A. Jones. The secretary was then instructed to cast the vote of the Society in favor of the officers and committees as shown on page ix of these Proceedings.

REPORT OF THE EXECUTIVE COMMITTEE

IMPROVEMENT OF LIBRARY FACILITIES IN HORTICULTURE

In the presidential address for the twenty-seventh convention, special reference was made to the need of further development and improvement of library facilities, particularly for advanced students and research workers in horticulture. Your committee, in conference with a committee from the American Library Association, has given this subject further consideration and wishes to submit the following as a progress report:

1. *The organization of advanced systematic courses in the use of the library, with special reference to the needs of horticultural students.* This course would be designed for graduate students and would lay special emphasis on sources of material, bibliographic works and would be given by the staff of the library department. The committee also recommends that a model syllabus and set of lectures and problems for such a course be prepared by a committee from the American Library Association.

2. *Compilation of reading lists of books and periodical sets to be used in connection with courses in horticulture.* The books on such a list would be chosen with the aim of giving the students a broader view of the subject of horticulture as a whole and of acquainting him with its important literature and source material. The compilation of such lists to be made by a committee from the American Library Association in coöperation with the horticultural workers in the various state institutions. The term horticulture is herein considered to embrace pomology, vegetable crops and floriculture. This study would be similar in a measure to the work done in the field of chemistry as outlined in *Science* 66:385-389, 1927, and would represent a list of essential and necessary library tools in the field of horticultural research.

3. *Bibliographic cards.* We recommend that the Office of Experiment Stations of the U. S. Department of Agriculture consider the feasibility of publishing bibliographic cards, author and subject, covering the contributions from the state experiment stations as is now being done for publications of the U. S. Department of Agriculture.

4. *A full cataloging by each institution of its own publications, especially the bulletins and memoirs issued by the experiment station and all the scientific series published by the institution.* The preparation of card indexes covering the publications of each institution would facilitate the use of its library. This activity would be coöordinated with the bibliographic cards referred to in paragraph 3.

5. *Compilation of complete special bibliographies in connection with certain projects that are subjects of research at numerous institutions.* A bibliography covering some of the major projects in horticulture, as for example hardy stocks, etc., would be of material assistance to any worker taking up a special problem in that particular field, and the compilation of such bibliographies would seem to be an appropriate activity of the Office of Experiment Stations.

Upon vote of the Society the President was authorized to appoint a committee to carry on further the activities of the Society in regard to library and indexing facilities.

RECOMMENDED CHANGES IN THE SOCIETY CONSTITUTION AND BY-LAWS

The committee recommends the following changes in the Constitution: That ARTICLE III be amended to read as follows:

Voting Members—Any person who has a baccalaureate degree and holds an official position in a university, college, experiment station, or Federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Non-voting Members—Any person holding a baccalaureate degree shall be eligible to membership in this class.

It will be noted that the effect of a proposed change in the Constitution regarding qualifications for membership has the effect of making provision for an additional group known as non-voting members. The scholastic requirements for this group are the same as for voting members but they do not hold an official position in a Government institution and do not have voting privileges. Graduate students and research workers in commercial lines will be eligible for membership in the non-voting class.

That Article V be amended to read: The officers shall consist of a President, three Vice-Presidents,.....

BY-LAWS

The committee recommends that SECTION 2 of the By-Laws be amended to read as follows:

SEC. 2. There shall be a Committee on Nominations consisting of five (5) members, who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this committee, at the following meeting, to suggest to the Society nominees for the various committees, and one nominee for each of the offices for the ensuing year.

The recommended amendment for SECTION 2 of the By-Laws eliminates the provision requiring two (2) nominees for office of president.

The committee recommends that SECTION 6 of the By-Laws be changed to read as follows:

SEC. 6. The annual dues of the Society shall be four dollars.

The changes to the By-Laws were passed by the Society. The changes to the Constitution were read and accepted, final vote, as specified by the Constitution being deferred until the next regular annual meeting of the Society.

RESOLUTIONS

The following resolutions were adopted by the Society: *Resolved*, That the Office of Experiment Stations, United States Department of Agriculture, be urged to provide for the publication of bibliographic cards, author and subject, for the bulletins of the state experiment stations.

Resolved, That the management of the St. Charles Hotel be given our expression of appreciation for the services rendered and courtesies extended to this Association during the twenty-eighth meeting of the Society. Also that we express our especial thanks to Professor J. C. Miller and other members of the local committee on arrangements for their careful planning for the comfort, pleasure and instruction of the Society membership during our convention.

LAURENZ GREENE,
ARTHUR S. COLBY,
KNOWLES A. RYERSON,
Committee.

TREASURER'S REPORT FOR 1931

Receipts

Dues collected during 1931	\$1,543.50	
Reports sold during 1931	971.35	
		<hr/>
		\$2,514.85
Interest on money in savings accts.		54.44
Balance on hand Dec. 15, 1930		2,035.81
		<hr/>
		\$4,605.10

Expenditures

Dec. 22	W. F. Humphrey, programs	36.50
Dec. 22	M. S. Barrett, mimeographing	10.00
Dec. 22	Marjorie Rogers, mimeographing	6.40
Dec. 26	H. B. Tukey (Society expenses, Cleveland, \$65.00 less \$18.50 refund)	46.50
Jan. 5	Postmaster, stamps	10.00
Jan. 9	G. E. Stechert & Co., report returned.....	3.50
Mar. 18	W. S. Blair, overpayment of dues	3.50
Mar. 30	Secretary's fees for 1931.....	250.00
Apr. 13	Postmaster, stamps for mailing report	25.00
Apr. 21	R. C. Dikeman, purchase of old reports for resale	15.00
Apr. 27	W. F. Humphrey, letterheads, envelopes, billheads	24.60
Apr. 27	W. F. Humphrey, printing 1930 Proceedings....	2,222.87
Apr. 29	Postmaster, stamped envelopes	22.60
May 25	Mrs. Albert Dickens, purchase of old reports for resale	15.00
May 26	Postmaster, stamps	10.00
Jun. 23	Postmaster, stamps	15.00
Sept. 21	Postmaster, stamps	10.00
Nov. 25	Postmaster, 1½c envelopes for mailing circulars.....	8.74
		<hr/>
	Total Expenditures	\$2,735.21
	Checks returned on account bank failures.....	10.50
		<hr/>
		\$2,745.71
	Balance on hand Dec. 15, 1931	1,859.39
		<hr/>
		\$4,605.10

Respectfully submitted,

H. B. TUKEY, *Treasurer.*

Audited and found correct,

E. L. OVERHOLSER,

W. G. BRIERLEY,

Committee.

Some Relationships Between Tree Response and Internal Composition of Shoots of the Peach¹

By F. P. CULLINAN,² *Purdue University, Lafayette, Ind.*

PEACH trees show a marked response to environmental changes as a result of the horticultural practices of pruning and orchard fertilization. By varying the environmental conditions in which the tree is growing, the amount of terminal shoot extension may be caused to vary from a few inches to 4 or 5 feet in length.

In some peach pruning experiments, it has been observed that the number of blossom buds per shoot may vary with the quality of shoot growth produced (1). It has also been observed that the blossom buds produced on shoots differing in length and diameter may vary in their hardiness with respect to low winter temperatures (2). It would be of considerable interest to know whether these differences are correlated with chemical composition of the shoots and whether the factors responsible for the differences can be affected by cultural treatments.

Terminal shoots were selected in three seasons from peach trees growing in two orchards of the Purdue University Agricultural Experiment Station. Shoots of varying length were selected late in the season of 1928 and the winter and spring of 1929 from 5-year-old Elberta trees growing on a sandy loam soil and receiving varying amounts of pruning. During the season of 1929 and the winter of 1930-31 terminal shoots were selected from 6-year-old Elberta trees growing on a clay loam soil in another orchard where the quantity and quality of shoot growth were varied by applications of nitrogen to the soil. The shoots were collected at about the same time of day on each sampling date and brought to the laboratory where they were cut up into small pieces and preserved in 95 per cent alcohol. Determinations were made on dry weight, soluble and insoluble nitrogen, reducing sugars, sucrose and starch. Only a summary of the results secured will be given here.

RESULTS

Preliminary studies made on samples of terminal shoots taken in 1928-29 from trees receiving varying amounts of pruning indicated differences in the chemical composition of qualitatively different shoots. The values for total nitrogen and sugar showed an increasing gradient from base to tip of the longer branched shoots. The basal and middle portions of long shoots which formed new fruit buds were relatively low in total sugars and nitrogen. The upper middle, tip, and laterals of the 1-year shoots showed an increase in total sugars and nitrogen in the combined bark and wood as compared

¹Published with the approval of the Director of the Purdue University Agricultural Experiment Station.

²Now with the U. S. Department of Agriculture.

with the basal portions. Wood and bark were not separated in these samples, and the differences may have been due in part to the relative amounts of bark and wood in the separate fractions. However, at the time of sampling in September, 1928, a comparison between laterals and short spurs of about the same dry weight, and which possessed about the same relative amounts of bark and wood in the sample, showed that short spurs contained a relatively greater amount of reducing sugars and sucrose and less soluble and insoluble nitrogen than the laterals. The short spurs contained about three times as many blossom buds as the laterals. As will be pointed out later, these values for total sugar may have been somewhat different on samples taken later in the season. The data secured indicated that peach shoots which are qualitatively and quantitatively different in length, diameter and position in the tree, exhibit considerable qualitative and quantitative variation in their chemical make-up.

In 1929 a block of 28 six-year-old Elberta peach trees growing in a clay loam soil in the Experiment Station orchard were given uniform pruning, but the amount of nitrogen fertilizer was varied. By this means it was hoped to bring about differences in length and quality of shoot growth which could be sampled during the season to study any change in internal composition. An analysis of the one-year shoots of the trees prior to the time of applying the fertilizer showed that their composition was fairly uniform and differences between plots were within the range of random sampling. None of the trees used showed any evidence of a nitrogen deficit at the beginning of these studies. The fertilizer treatments were: (1) no nitrogen; (2) moderate nitrogen,—a 3-lb. application before bloom; and (3) heavy nitrogen,—a 3-lb. application before bloom, 2 pounds after petal fall, and 2 pounds 6 weeks after petal fall. Samples of unbranched terminal shoots were selected as the unit of comparison between treatments at six different periods during the season, namely, (1) as blossoms were showing pink, (2) after petal fall, (3) seven weeks after petal fall, (4) mid-season, (5) after harvest, and (6) early winter.

In all cases where nitrogen had been supplied either before or after bloom, higher nitrogen content was noted in the new growth (Table I). Six weeks after petal fall, trees which received no nitrogen showed an appreciably smaller shoot growth than trees receiving nitrogen. The shoot growth of unfertilized trees was higher in dry weight and starch, and lower in soluble and insoluble nitrogen. By mid-season the terminal growth of the non-nitrogen trees had been completed and averaged only about one-third the length of heavy nitrogen trees. Starch continued to accumulate in the shoots of low nitrogen trees and reached its highest point in September. In late summer, starch began to accumulate in the high nitrogen trees and likewise reached its high point in September, although at that time it was less than that found in low nitrogen trees. Fruit buds were larger and more developed at this time on the non-nitrogen trees although more

numerous on the high nitrogen trees because of the greater total growth. No samples were taken between September and December, and it is not known just when starch ceased increasing. However, during this period there was marked disappearance of starch, and sugars showed an increase in the terminal shoots. Samples taken in early winter (December, 1930) showed the terminal shoots of high nitrogen trees to be slightly higher in starch than the low nitrogen trees. This may be due to the rate of hydrolysis, and it may have progressed farther on the non-nitrogen trees. The total nitrogen content of shoots receiving heavy nitrogen treatments was higher at all times throughout the season than in shoots from non-nitrogen trees.

TABLE I—COMPOSITION OF UNBRANCHED TERMINAL SHOOTS OF THE PEACH, IN PER CENT OF DRY WEIGHT, 1929

Date	Rows	Material	Treat- ment ¹	Length (Cms.)	Dry Weight	Total Sugars	Starch	Total Nitro- gen
4/8	12-13	1-yr. wood	—	40.7	44.48	3.29	2.04	.922
	14-15	1 yr. wood	—	40.3	44.14	3.04	2.71	.953
4/26	12-13	1-yr. wood	O-MP	35.7	47.23	3.17	1.91	.846
	14-16	1-yr. wood	N-MP	36.9	45.8	3.40	2.13	.870
6/14	13	New growth	O-MP	7.5	35.61	6.06	5.37	1.12
	14	New growth	N-MP	9.0	30.72	7.36	4.47	1.59
	15	New growth	HN-MP	11.2	31.10	5.54	5.09	1.54
	13	1-yr. wood	O-MP	33.6	49.1	3.50	3.66	0.65
	14	1-yr. wood	N-MP	35.4	44.3	3.58	2.61	0.76
	15	1-yr. wood	HN-MP	36.8	41.7	3.57	1.58	0.75
7/27	13	New growth	O-MP	13.5	50.8	3.62	5.60	.707
	14	New growth	N-MP	37.7	38.7	3.35	2.26	1.01
	15	New growth	HN-MP	36.7	46.4	4.19	2.84	.871
9/27	13	New growth	O-MP	10.3	45.5	3.22	8.11	.90
	14	New growth	N-MP	36.1	51.2	2.71	7.36	.78
	15	New growth	HN-MP	36.2	48.1	2.69	7.27	.95
	13	1-yr. wood	O-MP	37.0	59.5	2.77	7.95	.53
	14	1-yr. wood	N-MP	41.5	59.4	2.15	8.88	.45
	15	1-yr. wood	HN-MP	41.7	58.7	2.03	7.06	.44
12/30	13	1-yr. wood	O-MP	22.3	51.0	5.94	2.75	1.03
	14	1-yr. wood	N-MP	41.8	52.3	6.26	3.08	1.11
	15	1-yr. wood	N-HP	42.3	53.1	5.92	3.06	1.12

¹O=No nitrogen, N=Nitrogen, HN=High nitrogen, MP=Moderate pruning.

Analyses of terminal shoots made after terminal growth had ceased on all plots (September) did not show the marked differences in composition that might have been expected from the vegetative appearance and amount of shoot growth made by trees under the various treatments. Thus in the dormant seasons of 1930 and 1931, a year of no crop, total nitrogen in the terminal shoots of non-nitrogen trees was nearly as high, and in some instances higher, than in trees receiving large applications of nitrogen fertilizer. During the period of terminal elongation, however, total nitrogen was relatively higher in

the shoots of the high nitrogen trees. During the period before leaf fall when nitrogen would be expected to move from the leaves into the shoots, the increase in nitrogen in the shoots was greater relatively on the non-nitrogen trees. The values for starch in the terminal shoots were also much closer together for the different treatments during the late fall and winter than during the growing season. Determinations were not made to study what corresponding changes were made in other parts of the tree.

TABLE II—LENGTH OF SHOOTS PRODUCED ON UNFERTILIZED TREES IN TWO SUCCESSIVE SEASONS

Row	Treatment	Length, 1929 (Cms.)	Length, 1930 (Cms.)
13-3	No nitrogen in 1929 3 lbs. ammonium sulphate in 1930.....	9.9	38.3
13-5	No nitrogen in 1929 3 lbs. ammonium sulphate in 1930.....	10.6	40.3
14-4	3 lbs. ammonium sulphate in 1929 No nitrogen in 1930.....	34.4	17.8
14-3	3 lbs. ammonium sulphate in 1929 No nitrogen in 1930.....	18.6	11.4
14-2	3 lbs. ammonium sulphate in 1929 No nitrogen in 1930.....	20.2	12.8

Although nitrogen was not determined in the roots and other parts of the tree in the dormant season, it is probable that the total nitrogen reserve was higher in trees well supplied with nitrogen. This is indicated by the greater terminal extension made by trees in the season following nitrogen applications. With trees receiving no nitrogen fertilizer in 1929 but an application of 3 pounds in 1930, the terminal shoot growth was increased in length nearly four times. Trees which had received nitrogen in 1929 but none in 1930 produced terminal shoots about one-half as long as in the previous season (Table II). Where the number of growing points had been reduced by pruning on similarly treated non-nitrogen trees in 1930, terminal growth was markedly increased.

HARDINESS OF BUDS UNDER THE VARIOUS TREATMENTS

A temperature of -5 degrees F. occurred in December, 1929. Two weeks after the freeze, samples of terminal growth were taken for analysis. The percentage of live buds in a 100-gram sample of representative shoots taken from each plot is given in Table III. Approximately 55 per cent of the buds on short spurs and 45 per cent on the longer terminals of the non-nitrogen trees were killed, while only about 18 per cent were killed on the long terminals of the high nitrogen trees.

TABLE III—PER CENT OF LIVE BUDS FOUND IN 100-GRAM SAMPLES TAKEN DECEMBER 30, 1929

Row	Treatment	Average Length of Shoots (Cms.)	Number Live Buds	Number Dead Buds	Per cent Live Buds
13	No nitrogen.	22.3	76	60	55.9
13	No nitrogen.	7.2	123	149	45.2
14	3 lbs. (NH ₄) ₂ SO ₄ (before bloom)	41.8	214	55	79.5
15-16	7 lbs. (NH ₄) ₂ SO ₄ (before and after bloom).....	43.2	250	54	82.2

The chemical data (Table I) do not suggest the probable explanation for the greater hardiness of buds on the longer shoots. The only marked difference in composition between shoots from the various plots was that those shoots which bore the highest per cent of live buds were higher in reducing sugars. The longer shoots were also higher in total nitrogen throughout the growing season. Moisture content and composition of the buds were not determined. Blossom buds on the short spurs and terminals of low nitrogen trees were more developed in autumn than some buds on shoots of high nitrogen trees. Basal buds on long terminals and buds on the laterals of branched terminals were smaller in size. While it is probable that the factor or complex of factors responsible for the greater hardiness of the buds lies in the physiochemical relationships in or near the bud rather than in the shoot as a whole, it does appear that these factors may be associated with the nutritional conditions of the tree. This may also affect the time of fruit bud differentiation in the shoot and the beginning of the period of rest.

The growth of the peach is quickly affected by changes in nutritional conditions as evidenced by the quantity and quality of growth produced with a heavy crop, when nitrogen fertilizers are withheld or when a large part of the top is removed in pruning. The data secured in these studies indicate that shoot growth may vary in internal composition under different conditions of nutrition. Further data are needed in a study of the correlation of these conditions to blossom bud formation and hardiness of buds.

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Preliminary Report on Relation of Soil Moisture and Leaf Area to Fruit Development of the Georgia Belle Peach^{1,2}

By IVAN D. JONES, *North Carolina State College, Raleigh, N. C.*

EARLY fruit thinning experiments clearly indicated that fruit load per tree and fruit quality are closely associated. The more detailed and carefully controlled experiments by Magness and other investigators have emphasized that there exists direct relation between relative leaf area per fruit and fruit size and quality.

Soil moisture studies by Viehmeyer, Hendrickson, Magness, and Furr and others have established the connection between available soil moisture and tree behavior. It has been demonstrated that soil moisture is one factor which limits stomatal movements, and therefore actually regulates the effective leaf area of a tree.

The present study was undertaken in the Sandhill section of North Carolina. The purpose of this project was to determine, for the peach, the effect of leaf area upon fruit size and quality, and the interrelationship which exists between soil moisture, leaf area, and fruit development.

The soil in the region in which this experiment was conducted consists of Norfolk coarse sand. With the exception of the surface 6 inches the soil is quite homogeneous, at least to the depth of four feet.

In general, heavy fertilization is required to make this soil productive. This condition and the fact that sectional orchard practices favor heavy pruning results in the formation of a relatively small, open tree.

The experimental plots consisted of groups from two to five trees each and were established in close proximity.

Soil moisture treatments were carried out as indicated below :

Irrigated plot	Plot irrigated at prescribed periods.
Mulch plot ¹	Surface covered with a 12-inch layer of pine straw. This covering was to conserve the moisture gained by seasonal precipitation.
Dry plot	Plot protected by covering of mulch paper. The strips of paper were overlapped and sealed to make the cover water-proof.
Average orchard condition	This plot received no artificial moisture control.

¹NOTE:—This plot has not received further treatment in this report as it paralleled closely in most details the values given by the irrigated plot.

²This is a report of a cooperative project between North Carolina State College and the Division of Horticultural Crops and Diseases, U. S. D. A.

³Published with the approval of the Director of the N. C. Agricultural Experiment Station as Research Paper No. 52.

Soil moisture determinations were made on each plot at short intervals during the growing season. Samples were taken by means of an auger at a distance of approximately 10 feet from the tree and to a depth of 4 feet. Each 1-foot level sampling was separately well mixed and a portion of this soil was dried at 110 degrees for 36 hours. The moisture content of the soil is expressed as percentage water on dry weight basis.

The relative leaf area studies were made by using ringed branches on which the desired leaf-to-fruit ratios were established. The branches selected for experiment were mainly comparable 1-year-old terminals from 2 to 3 feet in length. Ringing was done in the conventional manner by the removal of a $\frac{1}{2}$ -inch strip of bark and cambial layer from around the branch. The rings were made near the base of the 1-year-old wood. Ringing was done on or near the date May 28.

Ratios of 15, 30, 45, 60, and 90 leaves per fruit were established in replicate on each of the plots receiving different soil moisture treatment. Table I indicates the number of branches of each leaf-to-fruit ratio ringed on each plot. Fruit circumferences were taken at time of ringing and at successive intervals throughout the growing season. The volume of the fruit has been calculated from these circumference measurements, assuming the fruit to be spherical in shape.

Stomatal movements were followed by microscopical observation of dry mounts of strips from the lower epidermal covering of leaves, according to the procedure suggested by Magness and Furr in apple studies. These observations were made in the field at short intervals on frequent dates during the fruit growth. This method of observation proved to be entirely satisfactory for peach leaf study. Stomatal behavior was observed on leaves taken from unringed branches of the various experimental trees.

It was found that under normal seasonal conditions the stomata of the peach leaves opened very soon after exposure to the direct rays of the morning sun. With the leaves on the shaded side of the tree, stomatal opening was delayed from 30 to 60 minutes. Thus, on cloudless mornings the stomata of leaves on the sunny side of the tree were well open at about 6:15 to 6:30. On cloudy mornings stomatal opening for all leaves was delayed for an hour or more.

Fig. 1 by means of the bar diagram represents the record for stomatal behavior of the leaves from trees receiving different soil moisture treatments during the season. On certain days the stomatal movements were not followed until less than 25 per cent of the stomata remained open. These days are indicated by means of partially cross-hatched bars. The completely shaded portion represents hours during which stomata were observed to be open. Stomatal closure at these times took place some time during the period represented by the cross-hatched section. This figure also represents the seasonal soil moisture fluctuations for each plot, with dates and rates of precipitation and irrigation.

Field observation of the leaves on days not excessively hot and dry

and when soil moisture was abundant indicated that the maximum length of time during which 25 to 50 per cent of the stomata remained open was about $10\frac{1}{2}$ hours, or from 6:30 a. m. to 5:00 p. m. Fig. 1 represents the effect of decreasing soil moisture upon stomatal behavior of the leaves.

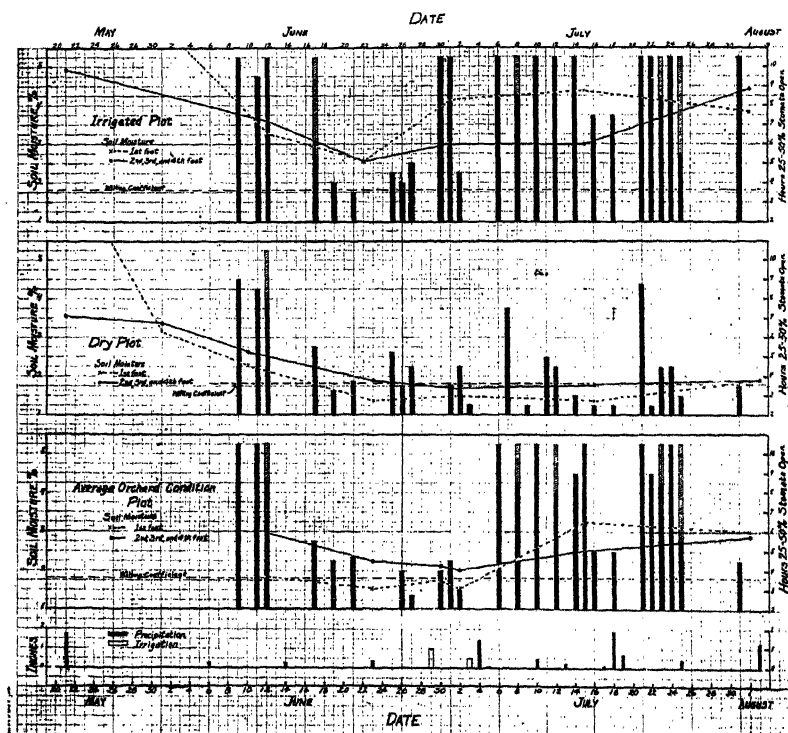


FIG. 1.—Seasonal soil moisture fluctuation of different plots and stomatal movements of leaves from trees growing on these plots.

June was a hot and almost rainless month. Accordingly, the soil moisture was rapidly depleted. It will be seen that on every plot during the latter part of June the stomata closed much earlier in the day than during the first of the month. Also it will be observed that as a result of a moderately heavy irrigation on June 29 the stomata of leaves from the irrigated plot were open the entire $10\frac{1}{2}$ -hour period for the days immediately following the irrigation. With the dry and average orchard plots the dry condition prevailed for several days longer and the stomata of leaves from these plots were open less than half as long as from the above mentioned plot.

With the rainfall of July 3 both the irrigated and average plot were well soaked. This gain of soil moisture is clearly indicated by

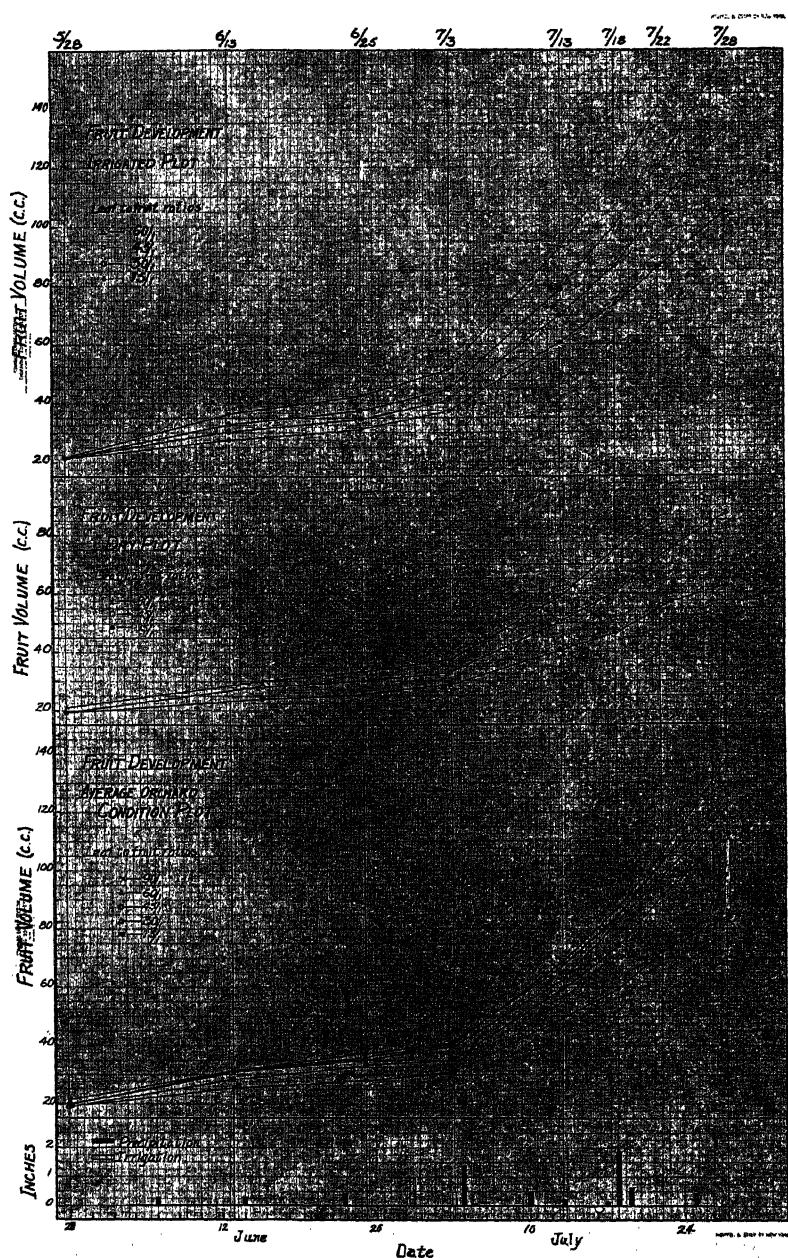


FIG. 2.—Fruit development from trees on experimental plots.

TABLE I—RATE OF GROWTH OF FRUIT ON RINGED BRANCHES
(With Reference to Plots Receiving Different Soil Moisture Treatments)

Location and Treatment	Leaf to Fruit Ratio	No. Ex-periment Branches	No. Fruit Measured	Fruit Volume at Successive Dates of Observation									
				At Ringing	6/13/31	6/25/31	7/3/31	7/13/31	7/18/31	7/22/31	7/28/31	At Harvest	
Average orchard condition plot—no artificial moisture control	15/1	8	61	19.38	25.55	28.67	31.06	49.38	59.55	72.05	84.61	94.06	
	30/1	11	52	19.30	28.64	33.27	35.57	59.87	74.32	91.42	112.42	118.59	
	45/1	6	19	20.00	30.92	35.24	39.95	62.91	80.28	97.99	122.44	137.61	
	60/1	5	18	21.61	31.85	37.60	41.77	67.98	84.54	103.29	126.18	133.26	
	90/1	4	7	21.10	31.75	36.84	40.41	68.13	87.03	105.29	138.54	137.59	
Irrigated plot—irrigation at prescribed intervals	15/1	7	41	21.34	27.66	31.27	37.17	60.72	73.37	86.34	105.29	104.36	
	30/1	2	6	21.93	30.61	34.84	41.73	69.71	86.59	106.58	133.77	142.11	
	45/1	9	25	21.78	32.85	37.48	45.01	78.38	100.59	120.18	158.19	139.47	
	60/1	2	4	21.34	36.63	42.51	51.63	92.46	117.14	140.74	—	140.74	
Dry plot—protected by water proof covering	15/1	5	25	—	6/16/31	—	—	—	—	7/23/31	—	—	
	45/1	7	14	19.59	24.11	26.21	29.02	40.71	46.59	57.49	62.88	64.08	
	90/1	1	1	19.85	27.97	30.23	33.09	50.53	60.81	76.05	87.22	86.60	
				21.31	30.11	33.51	37.16	59.37	74.48	89.03	—	100.07	

stomatal behavior on these plots. Truly, the dry plot also indicated a lengthened day during which the stomata were open; this was the result of a slight leakage of the water-proof covering. However, successive observations of leaf behavior and of soil moisture content

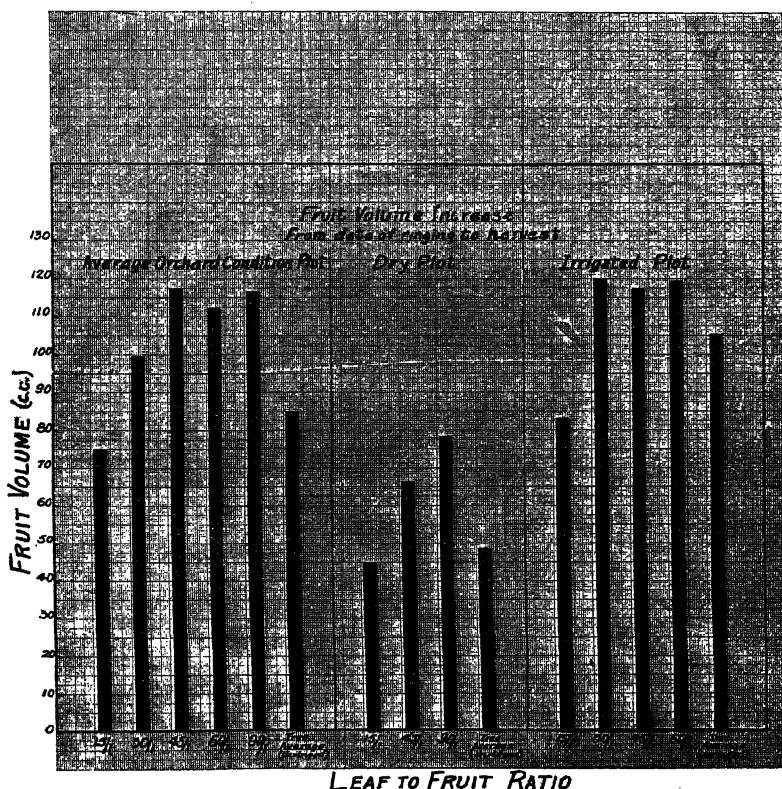


FIG. 3.—Fruit volume increase from date of ringing to date of harvest.

demonstrates that there was little gain of moisture by the dry plot during the entire season. Fig. 1 presents a definite contrast of soil moisture content between the irrigated plot and the dry plot. This contrast is just as marked in the comparison of the stomatal behavior of the same plots. In each case the average orchard condition plot yielded intermediate values.

Fig. 2 and Table I represent the rate of fruit growth from ringed branches on each plot. Fig. 2 points out three facts, namely, (1) an increase in leaf-to-fruit ratio resulted in an increase in size of fruit borne on the branches, (2) size of fruit for a given leaf-to-fruit ratio varied materially with the plot on which the fruit grew, and (3) the

relative rate of fruit growth for each plot throughout the season was essentially the same.

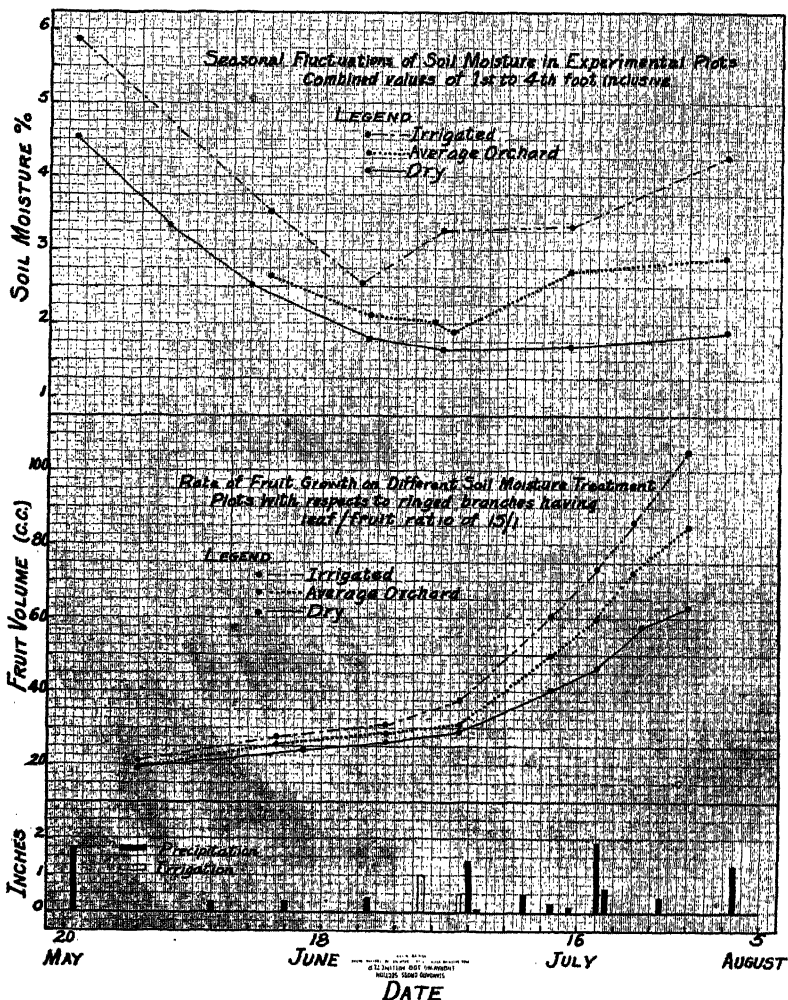


FIG. 4.—Relative rate of fruit growth on ringed branches having a leaf-to-fruit ratio of 15 to 1 on the different plots with respect to the corresponding seasonal soil moisture fluctuation for each plot.

It will be seen that in each case the fruit began its rapid period of growth immediately after July 3. This date coincides closely with the dates of irrigation and heavy rainfall. However, from the fact that the fruit on the dry plot also began its rapid growth at this time, it becomes apparent that an increase in soil moisture and the correspond-

ing increased leaf activity resulting from this is not the sole cause for this initiation of rapid fruit growth.

The fruit on the dry plot "sized up" and ripened with the moisture content of the first four feet of soil at or below its wilting co-efficient. Under this soil condition, however, 25 to 50 per cent of the stomata were open approximately 40 per cent of the time during the determined normal day.

Fig. 3 represents the increase in fruit volume from date of ringing to date of harvest from the ringed branches having different leaf-to-fruit ratios from trees in each experimental plot. It also represents total volume increase of average sized fruit from unringed branches on the same trees for the corresponding time period.

Fig. 4 represents the relative rate of fruit growth on ringed branches having a leaf-to-fruit ratio of 15/1 on the different plots with respect to the corresponding seasonal soil moisture fluctuation for each plot. This figure emphasized a point brought out by both Figs. 2 and 3, namely, fruit development on ringed branches having a given leaf-to-fruit ratio is related to the moisture content of the soil.

By a comparison of the fruit volume increase from unringed branches of trees receiving the different soil moisture treatments, the same conclusion will be drawn. Thus for the time period from May 28 to date of harvest the fruit increased on the dry plot 49 cc, on the average orchard plot 85 cc, and on the irrigated plot 106 cc. The trees on all three plots carried approximately the same fruit load. In other words, actual relative leaf area was approximately the same for trees in each plot but the effectual relative leaf area was decidedly different.

The following conclusions are drawn from the above study for this first season:

1. Increases in leaf-to-fruit ratios on ringed branches resulted in the formation of increasingly larger fruits, and to a limited extent in the hastening of fruit development and ripening.

2. Fruit borne on trees growing under distinctly different soil moisture conditions was correspondingly different in size, despite the fact that the leaf-to-fruit ratios were the same. Increase in moisture supply favored formation of fruit of increased size. This holds for either ringed or unringed branches.

3. Reduction of soil moisture under relatively constant atmospheric conditions is reflected in tree behavior by shortening of the period during which the stomata are open and accordingly functioning in food elaboration.

4. The minimum leaf area which favors the production of quality fruit varies markedly under different soil moisture treatments.

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The Relation of Leaf Area Per Peach to Physical Properties and Chemical Composition¹

By E. L. OVERHOLSER and L. L. CLAYPOOL, *State College of Washington, Pullman, Wash.*

BEACH (1) observed a correlation between size of peach leaves and fruit. The foliage of the Elberta, Crawford, and other large fruited varieties is relatively large as compared with the smaller, narrower leaves found on smaller fruited peaches, like Golden Prolific, Hill's Chili and especially on the natural seedlings that bear very small fruits. Studies by Haller and Magness (2), Magness, Overley, and Luce (3), and others showed that a definite minimum number of leaves per fruit is required in order to attain proper size and color of apples.

Studies were begun at the Irrigation Branch Experiment Station, Prosser, Washington, in the spring of 1931 to determine the relation of the average leaf area per peach upon (1) weight of individual fruits and size of individual leaves, and (2) the chemical composition of the fruit.

METHODS OF PROCEDURE

The fruit of branches on trees of early Elberta peaches were thinned on June 12 to give approximately 35, 50, 65, 95, and 125 leaves per fruit. One lot of branches with each leaf-fruit ratio was ringed on June 15 and one lot was left unringed. The ringing wounds were healed over by July 15 although it is probable that very little elaborated food was being translocated through the healed ringed portion at that time. Fruit harvest for the commercial crop began August 22; fruit from the branches in the experiment were harvested August 25 and 26. Fruit from the ringed branches matured from 1 to 2 days earlier than fruit from the branches not ringed. The color and maturity as harvested, however, of fruits from ringed and unringed branches were nearly the same. The variation in color and maturity of fruit between branches of the same treatment was greater than between branches receiving different treatments. The data pertaining to fruit from the ringed branches were more consistent than those obtained with fruit from the unringed branches.

RELATION OF LEAF AREA PER FRUIT TO WEIGHT OF INDIVIDUAL PEACHES AND SIZE OF INDIVIDUAL LEAVES

The data in Table I show a gradual increase in the size of the individual peaches with a greater number of leaves per specimen, from

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25 leaves per peach up to about 80 to 85 leaves per peach. The correlation and the differences in size as influenced by the number of leaves per fruit were more consistent and marked on the ringed than on the unringed branches. One hundred and fifteen leaves per peach gave only a slight further increase in size of fruit, when compared with 80 leaves per fruit, on the ringed branches, and on the unringed branches with 105 leaves per fruit, the size of fruit was apparently reduced, when compared with 85 leaves per fruit.

In this case there may have been such a limited number of fruits per given leaf area that during short daily critical periods of transpiration there was an insufficient reservoir of fruits for the leaves to draw upon to supply water. With the increase in the number of leaves per fruit, however, the average leaf area in square centimeters per gram of fruit produced was greater.

TABLE I—THE RELATION OF LEAF AREA PER FRUIT TO WEIGHT OF INDIVIDUAL PEACHES AND SIZE OF INDIVIDUAL LEAVES
(Early Elberta Peach)

No. Leaves per Fruit	Ave. Area (Sq. Cm.) per Leaf	No. Fruits Harvested	Leaf Area (Sq. Cm.) per Fruit	Ave. Wt. Individual Fruit (Grams)	Leaf Area (Sq. Cm.) per Gram of Fruit Produced
From ringed branches					
25	28.84	137	722.6	118.9	6.06
40	27.81	171	1226.5	134.0	8.97
60	26.71	138	1632.4	135.0	12.07
80	27.81	72	2277.6	174.5	14.19
115	29.42	99	3367.9	177.0	19.03
From unringed branches					
25	34.91	153	948.4	123.5	7.68
45	33.16	240	1522.7	126.0	12.13
65	27.68	193	1800.1	132.0	13.61
85	27.42	104	2238.8	160.0	14.00
105	26.84	64	2813.1	135.0	20.84

With the greater number of leaves per peach on unringed branches the average area in square centimeters per leaf was reduced. For example, the average area of each leaf when there were only 25 leaves per fruit was 34.91 sq. cm. while with 105 leaves per fruit the average area of each leaf was only 26.84 sq. cm. The number of leaves per fruit upon the ringed branches, however, seemed to have no relation to the size of leaves since they all averaged from 26.7 to 29.4 sq. cm. in size.

RELATION OF LEAF AREA PER FRUIT TO CHEMICAL COMPOSITION

Magness, Overley, and Luce (3) reported that the total sugar, total dry matter, and titratable acidity of apples and pears on ringed branches with large leaf surface were greater than those of fruit on the same tree with small leaf area. Haller and Magness (2) had pre-

viously reported similar findings with apples. The data obtained with peaches are shown in Table II.

TABLE II—THE RELATION OF LEAF AREA PER FRUIT TO CHEMICAL COMPOSITION
(Average ringed and unringed branches)

Ave. Number Leaves per Fruit	Per cents of Chemical Fractions in Composite Samples							
	Acid	Nitrogen	Ash	Moisture	Reducing Sugars	Sucrose	Total Sugars	Alcohol Insol. Acid Hydrolyzable Materials
35	1.210	0.114	0.5247	88.29	1.39	4.73	6.12	1.20
50	1.095	0.111	0.5140	87.90	1.74	5.25	7.01	1.10
65	1.108	0.103	0.4950	87.45	1.72	5.58	7.25	0.76
95	1.046	0.101	0.4737	87.24	1.35	5.99	7.34	1.19
125	1.112	0.094	0.5070	87.23	1.59	5.97	7.56	1.21

The 1 year's data in Table II indicate that the chemical composition of the peaches was influenced by greater number of leaves per fruit in that nitrogen and moisture percentage possibly tended to decrease, and total sugars and sucrose percentages tended to increase. There was a tendency, with the exception of the fruit having 125 leaves per specimen, for the percentage of ash to decrease with an increase in the number of leaves. The percentages of acid, reducing sugars, and alcohol-insoluble-acid-hydrolyzable materials fluctuated but showed no consistent trends. St. John and Morris (4) reported a possible correlation between the alcohol-insoluble-acid-hydrolyzable materials and maturity of apples. If this correlation exists in peaches the data indicate that the maturity when harvested advanced from 35 to 65 leaves after which it was less mature with greater numbers of leaves per fruit. While not shown in the table, the fruit from the ringed branches tended to average higher in per cent of ash, reducing and total sugars, than did fruit from unringed branches.

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The Relation of Leaf Area to Size and Quality of Peaches

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REGULATION of the size of peaches by thinning is a practice well founded on experimental evidence and observation. Increasing the number of leaves per fruit by removing some of the fruit is known to produce large increases in size of individual peaches, but practically no attempt has been made to justify the practice experimentally on the basis of leaf area and the ability of leaves to synthesize the materials necessary for the best growth and development of the peach. Necessarily the amount of food available to the individual fruit is a controlling factor not only in producing size in the fruit but quality as well. For the purpose of securing a definite idea of the relation of leaf area to size and quality, investigations reported here were begun in 1931.

TABLE I—THE RELATION OF NUMBER OF LEAVES TO SIZE AND QUALITY OF PEACHES

Number Leaves per Fruit	Leaf Area (sq. in.)	Initial Size of Fruit (cc.)	Final Size of Fruit (cc.)	Dry Weight as Per cent Fresh Weight	Reducing Sugars as Per cent Fresh Weight	Total Sugars as per cent Fresh Weight	Acidity ¹
<i>Elberta</i>							
5	34	22.9	69.3	12.07	1.88	5.39	46.4
10	68	27.1	95.8	12.39	2.24	7.61	49.2
20	136	27.6	117.4	12.73	2.37	7.56	48.1
30	204	28.3	119.0	11.80	2.16	7.46	44.5
40	272	27.7	137.8	12.62	2.18	7.50	44.7
50	341	28.1	147.5	14.35	2.41	8.80	47.2
75	511	28.2	162.0	14.66	2.43	9.04	51.6
<i>Late Crawford</i>							
5	36	15.5	42.5	10.62	1.58	4.63	73.0
10	72	18.7	78.5	13.49	2.19	8.11	58.1
20	143	18.9	117.2	15.43	2.55	9.69	57.5
30	215	18.4	115.8	16.51	2.74	10.38	56.0
40	286	19.6	128.3	17.38	2.96	10.74	59.5
50	358	19.7	124.9	17.38	2.80	11.21	63.8
75	538	19.4	133.7	17.16	2.76	10.84	60.7

¹Acidity expressed as number of cubic centimeters 0.1N NaOH required to neutralize fifty grams extracted fresh tissue.

The procedure in these investigations was similar to that used by Haller and Magness (1) with apples and Winkler (3) with grapes. Trees of Elberta and Late Crawford varieties growing in a 20-year-old orchard of the University of Maryland at College Park, Maryland, were used for the tests. On July 8, eight branches on each of five trees of each variety were ringed, and leaves or fruit were removed from the branches so that a complete series of eight leaf-to-fruit ratios was obtained on each tree. These ratios are shown in Table I as number of leaves per fruit. Each branch bore from 8 to 15 fruits when ringed, but through various causes some were injured

and dropped off. This loss of fruit was immediately compensated for by removal of leaves so that the initial ratios were maintained throughout the season. Since the ringing was done comparatively late, pits of Elberta peaches had begun to harden, and terminal growth had practically ceased. Almost two months intervened, however, between time of ringing and maturity of fruit.

Moisture was a limiting factor in the growth of the fruit for a brief period about four weeks prior to time of picking, no rains of any consequence having fallen between July 16 and August 9. Since the tendency of a limited water supply is to dwarf all fruits and thus decrease the effect of varying leaf area per fruit, greater difference in the size of the fruit might have been obtained had rainfall been ample throughout the season.

Circumference measurements were made at weekly intervals, though only the data at time of picking are presented here. The measurements have been converted to a volume basis as being more **nearly indicative of the actual growth of the fruit.** The average results are shown in Table I.

Elberta peaches showed a definite increase in size with increase in leaf area up to 75 leaves per fruit, with no indication that peaches **larger than $2\frac{3}{4}$ inches** might not have been obtained with a greater number of leaves. As shown graphically in Fig. 1, the greatest increase in size of fruit per individual leaf occurred on those branches on which the number of leaves per fruit was reduced to 5, 10, or 20. The curve, of freehand construction, is begun on the y axis at the average size of the peaches at time of ringing, assuming the fruit would make no growth without a source of food supply. In reality, fruit on the completely defoliated branches shrivelled and dropped within a few weeks after girdling. The size of fruit was increased greatly by small increments in number of leaves per fruit in the smaller leaf ratios, as indicated by the steep slope of the line. Five leaves produced fruit having a volume of 69 cc. (2 inches in diameter), 10 leaves 96 cc. ($2\frac{1}{4}$ inches in diameter), and 20 leaves 117 cc. ($2\frac{3}{8}$ inches in diameter). However, 10 leaves did not produce twice as great an increment in size as 5 leaves, and the fruit grown with 20 leaves was correspondingly less than double the size of the fruit grown with 10 leaves. Fruit on branches having a greater number of leaves per fruit than 20 were larger with increase in leaf area, but the increments per unit leaf area were smaller. Of the fruit grown with 75 leaves for example, the first 10 leaves of the 75 could have produced as great an increase in volume (68 cc.) from the time of ringing to maturity, as the remaining 65 leaves, (66 cc.), indicating that the efficiency of the individual leaf in food production decreased enormously when the opportunity for utilization of the products was lessened.

In the case of the Late Crawford variety, a greater variability in the averages for the size of peaches grown with the various leaf areas is evident, but the trend of the curve is identical with that of Elberta. With the greater leaf ratios the curve tends to flatten out

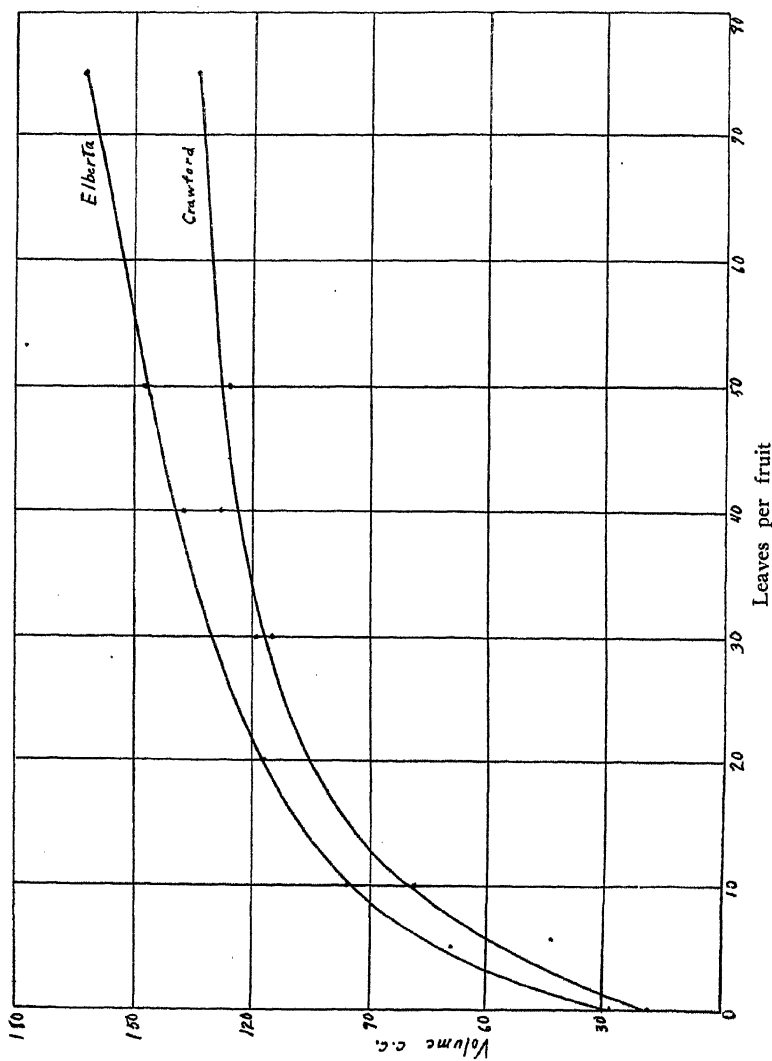


FIG. 1. Relation of leaf area to size of fruit.

more than the Elberta curve, indicating that a smaller gain in size of fruit may be expected from corresponding leaf areas. Seventy-five leaves produced a volume increment of only 114 cc., while 20 leaves increased the volume of the fruit 98 cc. This means, in the larger ratio, a reduction in the efficiency of the leaves in swelling the fruit, of 65 per cent; or compared with the 10 leaves per fruit ratio, a reduction of 75 per cent.

Flavor and quality in the fruit, within a variety, were associated with the number of leaves per fruit, as evidenced by large differences in quality between fruits which were grown with the various leaf ratios. Peaches grown with 5 and 10 leaves per fruit were of exceedingly poor quality, tasting bitter, flat, and very disagreeable. When grown with 20 or 30 leaves the fruit was considerably sweeter, with a good flavor, while with 40 or more leaves the peaches were of exceptionally good flavor and quality.

Quality in peaches is difficult to determine analytically but to a large extent it is dependent upon the sugar and acid content. With the Elberta variety fruit grown with 5 leaves had only 5.39 per cent sugar (Table I), while fruit grown with 10 leaves had 7.61 per cent. Further increase in sugar content was not obtained with increase in leaf area to 40 leaves per fruit; but fruit grown with 50 leaves had 8.80 per cent sugar and with 75 leaves 9.04 per cent, increases of more than 1 per cent over that grown with 40 leaves.

The greatest acidity in the fruit was obtained with the extremes of leaf areas employed, fruit grown with 10 and 75 leaves having a relative acidity of 49.2 and 51.6, compared with fruit grown with 30 leaves having a minimum acidity of 44.5.

The results secured from the Late Crawford tests were practically identical with those obtained with Elberta. With increase in leaf area per fruit a steady increase in sugar content resulted, fruit grown with 5 leaves having a minimum of 4.63 per cent sugar and fruit grown with 50 leaves having a maximum almost $2\frac{1}{2}$ times as great, 11.21 per cent. The minimum acidity again occurred in fruit grown with 30 leaves, acidity increasing with smaller or larger leaf areas per fruit. The greater acidity of the fruit grown with the smaller leaf areas undoubtedly had a deleterious effect on quality since it was accompanied by a low sugar content. In the fruit grown with the larger leaf areas, the greater acidity, accompanied by an increase in sugar content, might be considered as improving quality.

Reducing sugars were affected but little by varying leaf area, most of the differences in sugar content occurring in the non-reducing fraction. It is significant that the per cent of dry material in terms of fresh weight should increase with increase in leaf area per fruit. This is especially true with the Late Crawford variety. On a dry-weight basis, the differences in sugar content between the various leaf-to-fruit ratios were practically negligible, indicating that leaf area had practically no effect in changing the proportion of sugars to other dry matter constituents. The differences in

sugar content as noted were chiefly due to the fact that the smaller peaches contained considerably more water than the larger fruit.

Consequently, considering the amount of dry matter produced, the larger leaf areas produced more actual peach tissue than the relative sizes would indicate. In the case of Late Crawford, were the fruit grown with 75 leaves to contain as much water as the fruit grown with 5 leaves, the value of the growth increment of the former would be five times larger than that of the latter instead of only three times, as the actual sizes show.

The greater concentration of carbohydrates in the fruit, and presumably in twigs and leaves also in the branches bearing the larger leaf area per fruit, may be responsible for the decreased efficiency of the leaves in sizing the fruit. A limited number of observations indicated that the stomata on the heavily loaded, ringed branches remained open during the day for a longer period than the stomata in leaves on branches with greater leaf areas per fruit. This is in accordance with later studies with peaches, and with observations of other workers with apples (2) where the presence of fruit on the trees resulted in the stomata remaining open somewhat longer than when the fruit was picked. These data indicate that an accumulation of carbohydrates is a factor in the time of stomatal closure, which, in turn, may have been a factor in food manufacture.

The results of these tests clearly indicate that thinning in any amount reduces the total volume of the fruit produced, and the heavier the thinning the greater will be the reduction of the crop. The number of leaves per fruit to be left after thinning will vary with varieties and within a variety. Vigor of the tree, with which size of leaf is correlated, and the moisture supply also are important factors to be included. It seems, however, that under the conditions of the experiment 30 or 40 leaves per fruit are desirable, when size and quality of the fruit and future performance of the tree are considered.

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Some Fruiting Responses of the Peach to Applications of Nitrate of Soda

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DURING the season of 1931 an investigation was conducted on the influence of the application of NaNO_3 upon date of maturity, keeping quality, and chemical composition of the fruit of Elberta peach trees.

Ten uniform 6-year old trees of moderate vigor, growing in a clay loam soil with sandy clay subsoil were used. Clean culture with a fall cover crop of vetch has been practiced each year. The five treatments of two trees each were 0, 3, 6, 9, and 12 pounds of NaNO_3 per tree. One-half was applied March 6, 1 week before full bloom, and the remainder May 9, to reduce leaching losses during March and April. A supplemental application of $4\frac{1}{2}$ pounds of 16 per cent superphosphate and $\frac{1}{2}$ pound of 48 per cent potassium sulfate was made to each tree March 10.

Pressure tests were used to measure rate of softening. They were made through the skin with a Blake pressure tester (1) using the 3/16-inch plunger. Each sample consisted of 25 fruits over $2\frac{1}{4}$ inches in diameter. From each picking a sample was taken on the day of picking, 3 days later, and 5 days after picking. During the interval from picking until the final test, the fruits were kept in common storage at an average temperature of 85 degrees F.

The pressure was recorded, in the following order for each of the following five positions, namely, (1) on left cheek (when facing suture as fruit hangs on tree), (2) on opposite or right cheek, (3) at suture, (4) opposite suture, (5) at apex. All tests except those at the apex were made near the equator of the fruit. All fruit was picked in approximately the same stage of maturity, using a pressure of 8 pounds in position 1, as the standard.

The latest approved A. O. A. C. methods were used for all chemical determinations except water soluble nitrogen which was determined by the method of Nightingale (4).

The seasonal weather conditions were very variable. One period of drouth, accompanied by temperatures of 90 to 100 degrees F., occurred during the latter half of May and the first half of June, followed by another, with temperatures of 80 to 90 degrees F., from June 20 to July 13. Heavy rains of 4.07 and 5.50 inches occurred on July 23 and 24, respectively, but since the soil was abundantly supplied with moisture from July 13 until after harvest it does not seem probable that these two rains had any effect upon the firmness

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of the fruit. Consequently, differences in the firmness can be largely attributed to the nitrate supply.

The data of Table I show that increasing the amounts of NaNO_3 per tree delayed ripening 3 to 6 days, the amount of delay increasing with

TABLE I—PICKING DATES OF THE DIFFERENT TREATMENTS

NaNO ₃ Pounds per Tree	July		August					
	27	30	1	3	5	7	10	12
0	×		×	—				
0	×		×	+				
3		+	×	×	+			
3	—		×	×	+			
6				—	×	×	+	
6			—	+	×	×		
9		—		×	×			
9				×	×	×	+	
12				×	—	×	—	—
12				×	+	×	—	—

— = less than 100 fruits. + = 100 fruits or more. × = pickings used for testing and analyses.

the amount of NaNO_3 applied. There was also a tendency, particularly in the trees receiving 12 pounds of the NaNO_3 , for ripening to be less uniform, necessitating more and smaller pickings. These results are in general agreement with the reports of other investigators.

TABLE II. PERCENTAGE DECREASE IN POUNDS PRESSURE

NaNO ₃ Per Tree		Picking to Third Day				Picking to Fifth Day			
		Per cent Decrease		Gain or Loss	Students' Odds	Per cent Decrease		Gain or Loss	Students' Odds
A	B	A	B			A	B		
0	3	47.58	45.57	—2.01	3.7:1	62.96	61.55	—1.41	2.72:1
0	6	47.58	51.64	4.06	22.7:1	62.96	64.10	1.14	2.18:1
0	9	47.58	52.39	4.81	88.7:1	62.96	61.57	—1.39	3.85:1
0	12	47.58	50.71	3.13	6.6:1	62.96	58.37	—4.59	16.9 :1
3	6	45.57	51.64	6.07	16.0:1	61.55	64.10	2.55	91.6 :1
3	9	45.57	52.39	6.82	119. :1	61.55	61.57	.02	1.03:1
3	12	45.57	50.71	5.14	361. :1	61.55	58.37	—3.18	3482 :1
6	9	51.64	52.39	.75	1.58:1	64.10	61.57	—2.53	8.71:1
6	12	51.64	50.71	— .93	1.75:1	64.10	58.37	—5.73	8
9	12	52.39	50.71	—1.68	4.43:1	61.57	58.37	—3.20	14.2:1

Table II shows the percentage decreases in average pressure from picking to the third day and from picking to the fifth day. The difference in the percentage decrease of the two extreme treatments was not significant in the first three days after picking. While significant differences existed between some treatments, no definite decrease trend occurred. There is an indication that the fruit from the high treatment trees softened more rapidly than that from low treatment trees. This is shown in the comparison of the fruit from the 3- and 9-pound applications and the 3- and 12-pound applications. Fruit from the tree receiving the 12-pound application, however, did

not decrease in firmness quite so rapidly as that from the trees receiving 6- and 9-pound applications. Consequently, no apparent correlation existed between rate of application of the NaNO_3 and percentage decrease in firmness of the fruit during the first 3 days after picking.

TABLE III—PERCENTAGE DECREASE IN POUNDS PRESSURE, THIRD TO FIFTH DAY

NaNO ₃ per Tree (Pounds)		Percentage Decrease		Gain or Loss	Students' Odds
A	B	A	B		
0	3	27.52	28.54	1.02	2.08:1
0	6	27.52	25.82	— 1.70	3.77:1
0	9	27.52	19.03	— 8.49	6459. :1
0	12	27.52	14.96	—12.56	608.8 :1
3	6	28.54	25.82	— 2.73	3.13:1
3	9	28.54	19.03	— 9.51	73.0 :1
3	12	28.54	14.96	—13.58	273.5 :1
6	9	25.82	19.03	— 6.79	46.4 :1
6	12	25.82	14.96	—10.86	297.8 :1
9	12	19.03	14.96	— 4.07	14.0 :1

The data fail to show any definite trend in the percentage decrease in pressure during the five days following picking. The most significant differences were found in the comparisons of the 12-pound treatment with lesser treatments, showing in every case a smaller percentage decrease in fruit from the 12-pound treatment. This showed that the fruit did not decrease in firmness during the 5 days after picking in proportion to the amount of NaNO_3 applied.

TABLE IV—MEAN PRESSURE IN POUNDS IN DIFFERENT POSITIONS (500 FRUITS)

When Tested	Positions ¹		Mean Pounds		Gain or Loss	Students' Odds
	A	B	A	B		
When picked	1	2	8.18	7.84	.34	∞
	2	3	7.84	6.48	1.36	∞
	3	4	6.48	5.98	.50	∞
	4	5	5.98	5.84	.15	37.2:1
Third day	1	2	4.21	3.96	.25	∞
	2	3	3.96	3.29	.67	∞
	3	4	3.29	3.04	.25	∞
	4	5	3.04	2.85	.19	∞
Fifth day	1	2	3.18	2.94	.24	∞
	2	3	2.94	2.40	.54	∞
	3	4	2.40	2.32	.08	4999:1
	4	5	2.32	2.18	.14	106.4:1

¹Positions numbered as on first page.

The data in Table III show that the percentage decrease in pressure from the third to fifth day was not significantly different in the 0, 3, and 6 pound applications. In the 9- and 12-pound applications, the percentage decrease in pressure was significantly less than in the smaller applications. This is further evidence that rapidity of soften-

ing as measured by the pressure tester is not directly associated with rate of NaNO_3 application.

Table IV shows the mean pressure by position for all fruits tested at each of the three stages of ripeness. The data show that, for each of the three stages of ripeness, a significant difference existed between each pressure position and the one which followed it in testing order. The difference between the two extreme pressures decreased as the fruit ripened.

The data on fruit analysis presented in Table V show a decrease in percentage of both reducing and total sugars with increased rate of application. The percentage of both water soluble and total nitrogen increased as the rate of application of NaNO_3 increased. Calculations of coefficients of correlation between the pounds of NaNO_3 per tree and each of these factors show: for reducing sugars, $r = -.5000 \pm .1132$, $\frac{r}{\text{P.E.}} = 4.42$; for total sugars, $r = -.5176 \pm .1105$, $\frac{r}{\text{P.E.}} = 4.68$; for total nitrogen, $r = .9253 \pm .0187$, $\frac{r}{\text{P.E.}} = 49.48$; for water soluble nitrogen, $r = .7571 \pm .0644$, $\frac{r}{\text{P.E.}} = 11.76$.

TABLE V—ANALYSIS OF FLESH OF ELBERTA PEACHES (PERCENTAGE OF GREEN WEIGHT)

NaNO_3 per Tree (Pounds)	Moisture	Reducing Sugars	Total Sugars	Water Soluble Nitrogen	Total Nitrogens
0	86.74	2.54	7.78	.038	.085
3	88.08	2.60	7.65	.049	.107
6	87.67	2.17	7.23	.053	.129
9	88.16	2.20	7.18	.059	.142
12	88.32	2.30	7.14	.061	.150

The results secured concerning the effect of applications of NaNO_3 upon the keeping quality of fruits of the Elberta peach are in agreement with those of Degman (3). Blake (2) reports that fruit from a high carbohydrate tree is firmer in texture than that from a high nitrogen tree. Undoubtedly a greater difference in vigor existed between his high carbohydrate and high nitrogen trees than between the trees receiving the 0- and 12-pound applications used in this investigation. This is shown by comparing the total inches of shoot growth of the trees in the two investigations. The high carbohydrate tree made 5,828 inches of shoot growth, the high nitrogen tree 33,233 inches; while the tree receiving no NaNO_3 made 10,851 inches and the tree receiving 12 pounds of NaNO_3 made 18,645 inches. This seems to be a plausible explanation of the difference in results.

Since no significant decrease in firmness was produced by any of the quantities used, applications of NaNO_3 sufficient to maintain trees in a high state of vigor apparently are not detrimental to shipping quality. The fact that the fruit from all trees was well colored and not noticeably different in quality emphasizes this point. The application of NaNO_3 or similar nitrogenous fertilizers should be con-

sidered, however, only as an aid to proper cultural methods in securing maximum vigor and fruit production.

The data on the relative pressure in different positions emphasize the necessity of using the same set of positions when comparisons are made of the firmness of different fruits. Blake (1) reports that while some varieties are likely to vary in texture in different portions of the same fruit, others have a rather uniform texture throughout, but he does not give any data to show the relative pressure in pounds in the various positions. It seems that information on the degree to which commercial varieties vary in this respect is both desirable and necessary. This information will increase the efficiency of the pressure tester as a device by which firmness as an index of fruit maturity is determined.

The chemical analyses agree with those of Blake (2) for the sugar and nitrogen percentages. The greater amount of sugar in the fruits of the low nitrogen tree used by Blake in comparison to the no nitrate tree of this investigation was undoubtedly due to the difference in vigor previously explained.

CONCLUSIONS

Applications of NaNO_3 to 6-year-old Elberta peach trees of moderate vigor delayed maturity: the greater the application, the greater was the retardation. No definite relationship existed between rate of application of NaNO_3 and rapidity of softening of the fruit as measured by the Blake pressure tester.

Significant differences in pressure were found in five different fruit positions. The order of firmness was: left cheek (when facing suture with fruit hanging on tree), right cheek, suture, opposite suture, apex. A definite set of positions should be used to determine the relative firmness of different fruits. An increase in rate of application of NaNO_3 was associated with an increase in percentage of water soluble and total nitrogen and a decrease in percentage of reducing and total sugars in the fruit. Applications of readily available nitrogenous fertilizers should be considered only as a supplement to proper orchard practices in maintaining peach trees in their maximum vigor and productivity. Its effect on fruit firmness is apparently negligible.

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Some Vegetative Responses of the Peach to Applications of Nitrate of Soda

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IT has been reported that a high degree of positive correlation was found to exist between terminal growth and fruit production of the following season in peach trees (2, 3). Many investigators have found that peach trees make a much more profitable response to applications of NaNO_3 than to the applications of phosphorus or potassium fertilizers. For these reasons an investigation was started in the spring of 1931 to determine the vegetative responses of the Elberta peach to applications of NaNO_3 .

Trees were used to which 0, 6, and 12 pounds of NaNO_3 were applied. These trees were included in the investigation reported by Lott (4) who has explained the details of the material and methods. All shoot growth was measured on each tree and classified as shown in Table I. Shoots arising from terminal buds are designated primary shoots, those arising from lateral buds of current season's growth, secondary shoots, and those arising from lateral buds on 1-year or older wood lateral shoots.

The primary and secondary shoots used for chemical analyses were taken from the same terminal shoots. Twelve to eighteen-inch terminal shoots had to be used to get enough secondary shoot growth for an adequate sample. The laterals used for analyses were also 12 to 18 inches long. These samples were all collected on October 28, when about half of the leaves had fallen. There were more leaves remaining on secondaries than on primaries or laterals.

Primary and secondary leaf samples were taken from 10 terminal shoots 12 to 18 inches long on September 30, when the leaves were just beginning to fall readily. Leaves on primary shoots are called primary leaves and those on secondary shoots are called secondary leaves. Terminal shoots shorter than 12 to 18 inches did not have enough secondary growth to provide an adequate sample of secondary leaves. A random sample of 15 leaves was selected from each sample from each tree for measurements of leaf areas. The remainder was used for chemical analyses.

The data of Table I show that the tree receiving 6 pounds of NaNO_3 produced a greater number of primary, secondary, and lateral shoots 0 to 3 inches long than either of the other two trees. The 6-pound application also resulted in the most primary and lateral shoots 3 to 6 inches long, but the 12-pound application resulted in the greatest number of secondary shoots of this and all greater lengths. In all of the classes above 6 inches the 12-pound application produced the most shoots of all kinds, with the 6-pound application in second position. The tree receiving the 6 pounds of NaNO_3 had the great-

est total number of shoots, due primarily to the great number in the 0 to 3 inch class.

TABLE I—NUMBER OF SHOOTS OF DIFFERENT LENGTHS

NaNO ₃ Per Tree (Pounds)	Number of Shoots in Each Class (Inches)							Total Shoots
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	
Primary Shoots								
0	470	222	134	82	31	4	2	945
6	1161	325	198	96	22	3	—	1808
12	604	297	200	119	98	18	13	1349
Secondary Shoots								
0	55	102	48	14	2	—	—	221
6	97	106	74	15	—	—	—	292
12	60	119	137	42	6	—	—	364
Lateral Shoots								
0	358	278	191	45	16	3	2	893
6	634	401	196	87	13	2	—	1333
12	417	338	285	93	51	2	—	1186
Total Shoots								
0	883	602	373	141	49	7	4	2050
6	1892	832	468	198	35	5	—	3430
12	1081	754	622	254	155	20	13	2899

Cooper and Wiggans (2) found that shoots 3 to 10 inches long formed more buds per unit of growth than longer or shorter shoots. The unnitrated tree produced 975 shoots 3 to 12 inches long; the 6-pound application, 1300; and the 12-pound application, 1376. On this basis 12 pounds of NaNO₃ would be the most desirable quantity, but it is doubtful whether the increase of only 76 shoots of this length for the 12-pound application in comparison to the 6-pound application justifies the extra NaNO₃. The greater number of total shoots from the 6-pound application, coupled with the lesser number of long shoots in comparison to the 12-pound application indicates that 6 pounds was the most desirable rate. The yield records of next season should determine this point. The much greater number of twigs in all classes existing on both of the nitrated trees than on the unnitrated tree shows that the potential fruit production of Elberta peach trees in moderate vigor can be greatly increased by applications of NaNO₃.

In Table II it is shown that total inches of shoot growth of each kind increased as the rate of application increased. On account of its greater number of long shoots, the tree with the 12-pound application made the most total inches of growth, even though the 6-pound application produced the greater number of shoots.

The data on average length of shoot show that the great number of short shoots secured from 6 pounds of NaNO₃ resulted in the shortest average shoot length of each kind and the shortest average

length for the whole tree. The data suggest that the unnitrated tree lacked sufficient vigor to push many of its vegetative buds into growth, and that the 12-pound application produced enough vigor to develop

TABLE II—TOTAL INCHES OF SHOOT GROWTH AND INCHES PER SHOOT

	NaNO ₃ per Tree (Pounds)	Primary Shoots (Inches)	Secondary Shoots (Inches)	Lateral Shoots (Inches)	Total Shoots (Inches)
Inches of growth	0	4965	1225	4662	10852
	6	7068	1513	6151	14732
	12	8800	2614	7231	18645
Inches per shoot	0	5.25	5.54	5.22	5.27
	6	3.92	5.18	4.61	4.30
	12	6.52	7.18	6.10	6.43

a large number of long shoots. If short shoots produce the most buds per unit of length and are probably the most productive per unit length, the most desirable method of soil management in the peach orchard is one which produces the greatest number of short shoots. Obviously, an estimate of average growth length is not of great value, but the number of shoots of different lengths must be determined if shoot growth is to be used as an index of potential productivity. The desirability of the relatively great number of secondary shoots on the tree receiving 12 pounds of NaNO₃ is not known since there are no data concerning the productiveness of such shoots.

TABLE III—CHEMICAL COMPOSITION OF SHOOTS CALCULATION ON DRY WEIGHT BASIS

NaNO ₃ per Tree (Pounds)	Water Soluble N. (Per cent)			Total Nitrogen (Per cent)			Starch (Per cent)		
	Primary	Secondary	Lateral	Primary	Secondary	Lateral	Primary	Secondary	Lateral
0	.20	.39	.35	.88	1.21	1.12	17.59	20.73	13.45
6	.33	.42	.43	1.08	1.26	1.21	16.36	19.22	12.56
12	0.4	.48	.46	1.28	1.28	1.29	14.20	17.59	14.82
	Grams per Inch			Grams per Inch			Grams per Inch		
0	.0006	.0005	.0007	.0027	.0017	.0023	.0541	.0284	.0288
6	.0011	.0006	.0009	.0036	.0018	.0025	.0540	.0268	.0235
12	.0012	.0007	.0008	.0038	.0019	.0020	.0437	.0236	.0235

The percentage of both water soluble and total nitrogen increased in all types of shoots with increase in rate of application, as shown in Table III. The amount per unit of shoot length also increased in primary and secondary shoots as rate of application increased, but no definite trend occurred in the lateral shoots. The secondary shoots in every case had a higher percentage but a smaller amount per unit of shoot length than either primary or lateral shoots. The primary shoots had the greatest amount per unit of shoot length. The laterals had a higher percentage than the primaries and in most cases less than the secondaries, but had a greater amount per unit of length than the

secondaries and less than the primaries. The percentage of total nitrogen had the same trend as the water soluble nitrogen.

The percentage of starch decreased in the primary and secondary shoots with increase in rate of application, but no definite trend was found in the laterals. A greater percentage was found in the secondary shoots of each tree than in the primaries and usually the smallest percentage in the laterals. The amount of starch per unit of shoot length decreased in all shoots with increase in rate of application. The primary shoots had nearly twice as much per unit of shoot length as either the secondary or lateral shoots. There was little difference in the amounts found in secondary and lateral shoots of the same application of NaNO_3 . Blake (1) reports a greater amount of starch at the time of leaf fall in the branches of unfertilized trees than in the branches of trees which had received nitrogen. This agrees with the above data. The greater amount of starch in the primary shoots may be attributed to early inauguration of storage. No sugar was found in any shoot samples.

The data of Table IV show that the area per leaf increased with the rate of application of NaNO_3 . This was true of leaves from both primary and secondary shoots. The leaves from the primary shoots were in each case larger than those from secondary shoots. During the picking season it was noticed that the leaves on the tree of the 12-pound application were much larger than those on the trees of the smaller applications and particularly those on the no-nitrate tree. This difference appeared to be much greater than it was when the samples were taken. Unfortunately, no measurements of leaf area were made in mid-summer. This decrease in size difference from mid-summer to time of leaf fall, between leaves of high and low applications, may be attributed to the fact that the greater number of secondary shoots upon the high application trees used up the available nutrients and thus prevented further increase in leaf area, whereas, the smaller number of secondary shoots on the lower-application trees allowed more nutrients for leaf growth and a consequent increase in size until late summer. The time of taking leaf samples is an important factor in determining the relative effects of different treatments upon leaf area.

The grams of dry matter per leaf in both primary and secondary leaves increased with increased rate of application. The primary leaves of each treatment contained more dry matter than the secondary leaves.

The percentage of water soluble and total nitrogen increased in both primary and secondary leaves as the rate of application increased. The secondary leaves had higher percentages than the comparable primary leaves. The data show that the amount of water soluble and total nitrogen per leaf increased in both primary and secondary leaves as the rate of application of NaNO_3 increased. The primary leaves had greater total amounts than the secondary leaves in each treatment.

The data which have been presented show that applications of NaNO_3 to peach trees such as those used in this investigation greatly

TABLE IV—AREA AND CHEMICAL COMPOSITION OF LEAVES¹

NaNO ₃ per Tree (Pounds)	Per Leaf Area (Sq. In.)		Total N. (Per cent)		H ₂ O Soluble N. (Per cent)		Total N per Leaf (Gms.)		H ₂ O Sol. N. per Leaf (Gms.)	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
0	4.88	3.25	2.22	2.24	.29	.28	.0083	.0050	.0011	.0006
6	5.91	4.23	2.62	2.71	.30	.41	.0108	.0076	.0012	.0011
12	6.41	5.22	2.67	2.85	.38	.52	.0119	.0106	.0017	.0015

¹Chemical calculations on dry weight basis.

increased vegetative vigor. This should result in proportionate increases in production the following year, since it has been reported that vegetative vigor and production in the following season are correlated.

CONCLUSIONS

Applications of 0, 6 and 12 pounds of NaNO_3 to moderately vigorous 6-year-old Elberta peach trees resulted in an increase in shoot growth as the rate of application increased. The 6-pound application resulted in the most shoots and the greatest number of short shoots. The 12-pound application resulted in the greatest total inches of shoot growth, the most shoots over 12 inches long, the most secondary shoots, and the greatest average shoot length. The percentage and amount per unit length of both water soluble and total nitrogen in the shoots increased as the rate of application increased. The percentage and amount per unit length of starch in the shoots decreased as the rate of application increased. Leaf area increased with increase in rate of application. The percentage and amount per leaf of both water soluble and total nitrogen in the leaves increased as the rate of application increased.

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Preliminary Report of Effects of Time and Rate of Nitrate Fertilization on Growth and Yield of Elberta Peaches¹

By J. H. BEAUMONT, and C. F. WILLIAMS, *North Carolina State College, Raleigh, N. C.*

THE Sandhills of North Carolina is, as the name implies, a region of low flat-topped hills of sand. The elevation is approximately 500 feet. The soil is a coarse sand phase of the Norfolk series, very low in natural fertility and varying in depth from a few feet to 50 or more. In this region of poor soil, long hot summers, and relatively mild winters, a commercial peach industry of considerable and of lasting importance has developed. The production problems confronting the growers are varied, most of them are serious, and from the standpoint of experimentation the problems are of considerable scientific interest as well as of direct practical importance.

Of the problems, one of the more important is the effect of time and rate of nitrogen fertilization on yield, and more particularly on growth, hardiness, and disease resistance of the trees. Consequently, in the spring of 1929, with the cooperation of Mr. Richard Lovering, experimental plots in a block of 8-year-old Elberta trees were laid out. The orchard is located near Jackson Springs on sand which is perhaps about average for the section, certainly not the best. Annual winter vetch covercrops had been and are being grown. The trees have received rather severe pruning and through frost or conscientious thinning have never borne excessive crops. The vigor and condition of the trees may be called good for the section. At the time the plots were laid out the trunk circumference of the trees was secured. Later the plots were paired in such a way that the average trunk circumference of trees of the two paired plots was approximately equal to the average of all plots.

The fertilizer treatments appear in Table I. Nitrate was applied over a wide area around the tree and to half of the adjacent guard tree. The times of application vary with the season. "March" (Table I) signifies immediately preceding full bloom, "May" signifies after the crop has set or at the time of the "June drop," "August" signifies immediately after harvest, and "November" after possibility of renewed growth is over and as the trees are becoming dormant.

All treatments were started in the spring of 1930 except the two very late treatments (0-0-0-3 and 0-3-0-3) which were first applied in 1931 to plots which had previously received a 3-pound treatment split in three equal applications (1-1-1).

The data relative to trunk circumference increases and average terminal growth for the seasons 1930 and 1931 and the yield in 1931 are given in Table I. It was felt that although the 1930 yields were

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TABLE I.—EFFECTS OF TIME AND RATE OF NITRATE APPLICATION ON GROWTH AND YIELD OF ELBERTA PEACH TREES

Plot Number	Treatments, Pounds Nitrate				No. Trees		Average Increase in Trunk Circumference (Cm.)		Average Terminal Growth (Inches)		Average Yield Per Tree (Pounds) 1931	
	Nov.				Plot 1		1929 to 30		1930			
	March	May	Aug.	Nov.	Plot 1	Plot 2	1929 to 30	1930 to 31	1930	1931		
B20.....	6	-	-	-	7	-	-	3.43	-	-	16.9	175
B22.....	3	3	-	-	6	-	4.61	3.10	34.8	34.8	15.0	192
B7 B21.....	-	3	3	-	6	3	4.00	3.42	28.4	28.4	17.9	165
B9 B15.....	3	-	3	-	6	5	4.89	3.56	29.3	29.3	18.8	177
A9 B 18.....	-	3	-	3	5	7	4.28	2.56	25.6	25.6	14.9	157
A11A17.....	3	-	-	-	7	5	4.00	3.35	25.8	25.8	16.9	190
B5.....	-	3	-	-	7	-	3.69	3.95	20.3	20.3	18.9	183
A3 A6.....	-	-	3	-	5	5	3.55	3.67	16.1	16.1	22.7	160
A10A17.....	-	-	-	3	5	6	3.57	2.53	23.6	23.6	13.9	155
A13B6.....	1	1	1	-	3	5	-	-	-	-	-	-
A20B10.....	1	1	1	-	5	4	4.16	3.42	25.4	25.4	20.4	171
A12 B8.....	1	1	1	-	5	3	-	-	-	-	-	-
A4 A21.....	1½	1½	-	-	4	6	4.84	3.83	28.7	28.7	21.0	188
A5 B19.....	-	1½	1½	-	6	5	4.34	3.67	26.0	26.0	19.1	166
A7 A15.....	1½	-	1½	-	5	7	4.62	3.79	28.1	28.1	20.2	181
A8 B16.....	-	1½	-	1½	5	4	3.42	3.48	22.8	22.8	19.5	167
A18 B3.....	¾	¾	-	-	4	6	3.92	3.43	25.2	25.2	20.0	166
A19 B4 B13.....	-	¾	¾	-	5-	4-6	3.93	2.68	28.7	28.7	19.2	142
A22B11.....	¾	-	¾	-	6	4	3.25	2.15	22.9	22.9	18.9	148

for the $\frac{3}{4}$ - $\frac{3}{4}$ group which is the lowest and again indicates that these plots are receiving somewhat less than the optimum rate of application. The 6-pound treatments are not outstandingly better than the 3-pound treatments and indicate that at the present time the trees are perhaps receiving more nitrogen than is utilized efficiently. It is interesting to note further that the yield is in proportion to the rate applied at the early application excepting only the 6-pound early treatment.

The past season presented an unusual opportunity to study the effect of nitrate on the earliness of maturity of the fruit, due to the relatively long harvest period and to the careful "spot" picking practiced by Mr. Lovering. The contrasting effects of March and May applications are presented in Figs. 1 and 2, respectively, in which the cumulative percentage of the total crop harvested on the different picking dates are given.

In Fig. 1 it is seen that early applications of nitrogen delay maturity in relation to the amount applied. The $\frac{3}{4}$ -pound application is, however, relatively much earlier than the $1\frac{1}{2}$ - and 3-pound applications which matured at approximately the same rate. The $1\frac{1}{2}$ -pound plots were only slightly earlier than the 3-pound treatments, however. The 1-1-1 pound curve is common to the two graphs and serves as a ready means of comparison.

In Fig. 2 it is seen that May applications of nitrogen delay maturity more than early applications, especially the $\frac{3}{4}$ - and 3-pound treatments, while for some reason the $1\frac{1}{2}$ -pound line maintains approximately the same position it held in Fig. 1. The average date of maturity is, however, somewhat delayed by the later applications.

Seasonal Variations in Nitrogen Concentration in Twigs of Peach Trees Under Sandhills Conditions¹

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THE sandy soils of the peach section of North Carolina not only are the source of many problems in commercial peach production but also provide an excellent opportunity to study many phases of plant behavior under field conditions. Because of the low natural fertility and rapid rate of leaching of these sandy soils, they are especially adapted to problems dealing with differential nitrogen fertilization. The effect of applications of nitrate varying in time and amount on the response of the tree in growth and fruitfulness can be studied in relation to seasonal distribution of carbohydrates and nitrogen in the tree and the interrelation of all these factors with hardiness, dormancy, rest period, etc.

In this paper only differences in seasonal fluctuations in the total nitrogen of the shoots and wood produced by such a series of different treatments of nitrate fertilization will be reported. The trees used are located in bearing Elberta plots that are part of a major peach project. They were selected for uniformity in growth and condition before any differential fertilizers had been applied. This report is based on results obtained the first year of treatment. Obviously different results may be expected for succeeding years inasmuch as the trees will show the accumulative effects of the treatments. Previous work had shown that major differences in growth were associated with small differences existing during the preceding months in percentage of total nitrogen in the shoots and wood, also that differences in percentage of total nitrogen in the shoots between different treatments were greater than those between shoots of different lengths from similar treatments.

Three times of application are used, namely, in March just before bloom, in May after the crop has set, and in August immediately after harvest. The basic amount is 3 pounds of nitrate of soda, either applied at one time, or divided into equal applications and applied at combinations of two times or at each of the three times. On two other series of plots half and double this annual amount is applied in two equal applications at combinations of the three times. In this report these different treatments will be symbolized in formulas in which the first figure represents the application for March, the second for May and the third for August. Thus, 3-0-3 signifies 3 pounds in March, none in May, and 3 pounds in August.

The usual precautions were used in the collection and preservation of samples and the Gunning modification of the Kjeldahl method to include nitrates was used for the determination of total nitrogen.

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Data are expressed in percentage of dry weight. The medium treatment (1-1-1) will be used for a basis of comparison as a check.

When varying amounts of nitrate were applied in March to trees in the same condition, the percentage of total nitrogen in the shoots in April and May was proportional to the rate of application as shown in Table I.

TABLE I—RELATION OF NITRATE APPLICATION IN MARCH TO TOTAL NITROGEN IN SHOOTS OF PEACH IN APRIL AND MAY

Nitrate Applied in March (Pounds)	Total Nitrogen in Shoots Per cent of Dry Weight	
	April 23	May 13
0	2.292	1.059
$\frac{3}{4}$	2.713	1.177
1	2.55	1.200
$1\frac{1}{2}$	2.933	1.250
3	3.478	1.525

Thus with the exception of the percentage in April for the 1-pound amount, increasing amounts of application gave increasing percentages of total nitrogen in the shoots during the spring months. It will be noted that there is a rapid decrease in the percentage amounts from April 23 to May 13. The decrease from May 13 to August 5 was more gradual. This decrease occurs during the period of most rapid growth, consequently there is an actual increase in absolute amount of nitrogen per shoot during this period. This relation of composition of shoots to rate of March application is shown in each of the graphs. The percentages for April are not indicated as their amounts would have necessitated a much larger graph.

The similarity in the seasonal fluctuations in the percentage of total nitrogen between shoots and 1-year wood for two contrasting nitrogen treatments is shown in Fig. 1. The heavy application of nitrate in March and May has given a proportional increase in the percentage of total nitrogen in both shoots and wood during the spring months. In the case of the shoots this difference was maintained until August, but in the wood there was a greater depletion of total nitrogen at this time in the trees supplied with abundant nitrate. This was probably related to the greater response in growth in these trees. Where applications of 3 pounds of nitrate were made after harvest to low-nitrogen trees, the concentration in total nitrogen in the shoots and wood was greatly increased for the rest of the year as shown by the curve for the 0-0-3 treatment. This does not necessarily indicate a greater absolute amount for the trees as there was less total growth and very little, if any, growth after the application was made. However, the percentages for this treatment were high not only for shoots of average length for the treatment of 15 inches, but just as high for shoots of twice this length. Shoot growth on the other plot (3-3-0) averaged about 35 inches.

The effect of single applications of 3 pounds of nitrate applied at different seasons is shown in Fig. 2 compared with the check. Three pounds applied in March definitely increased the percentage of total nitrogen in the early season. All three treatments reached approximately the same minimum point in August (.695, .699, .701). After harvest the curves for trees that had received a nitrate application before this time, either March or May, were similar except that the more recent application (May) showed the more rapid increase in the first month. The 3-pound application after harvest gave a high nitrogen concentration in the shoots which was maintained the rest of the year as was explained with Fig. 1.

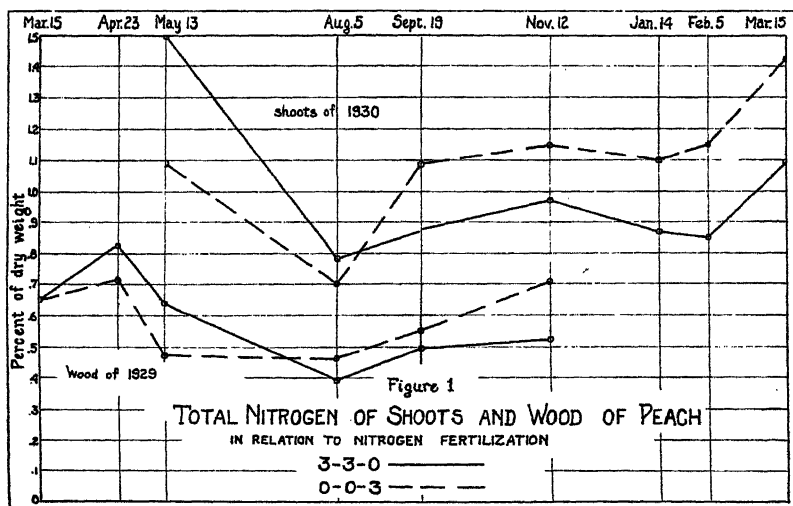


FIG. 1. Total nitrogen of shoots and wood of peach in relation to nitrogen fertilizer applications.

In the case of the check, the 1-pound application in March gave a higher percentage of total nitrogen in May than no fertilization, and with the additional 1 pound applied in May, maintained this difference until August. The 1 pound applied after harvest continued this higher concentration over trees receiving none at harvest at least until the middle of January.

The effect of different rates of application at different times in comparison to the check on the per cent of total nitrogen in the shoots is shown in Figs. 3, 4, and 5. These different graphs will be discussed together relative to different periods of the year, rather than each figure separately. With different amounts of nitrate applied in March (Figs. 3 and 5) the percentage of total nitrogen in May is proportional to the rate of the application. If a second application is made in May (Fig. 3) this difference in total nitrogen from different rates of application persists until August. In Fig. 4, showing the curves

for trees receiving their first application in May, this relation of fertilization to total nitrogen is again shown, although none show as high percentage amounts as the check which had received one pound in March.

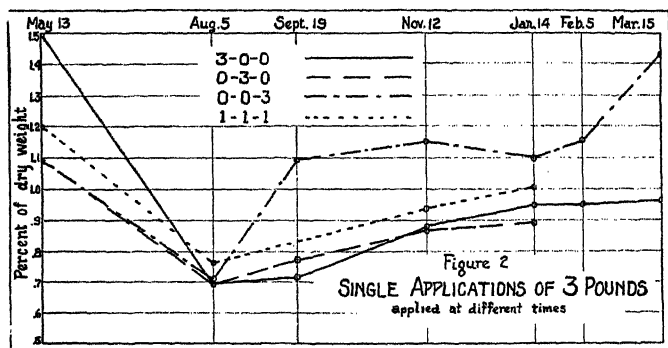
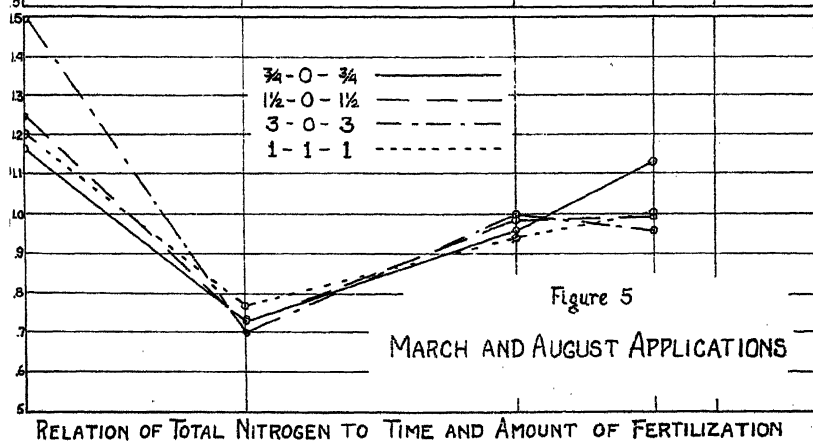
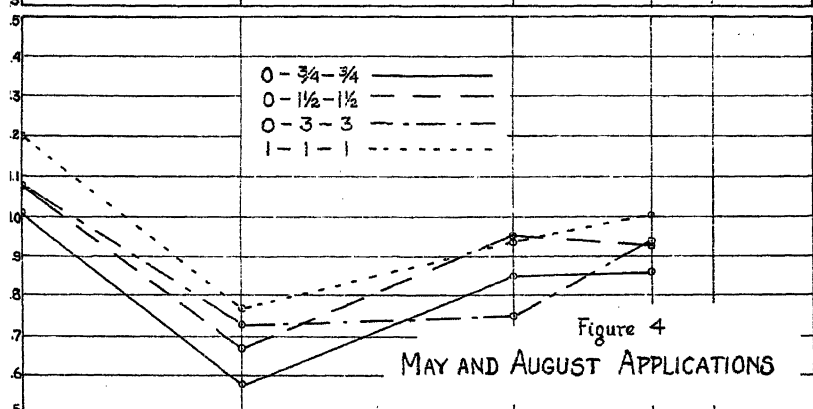
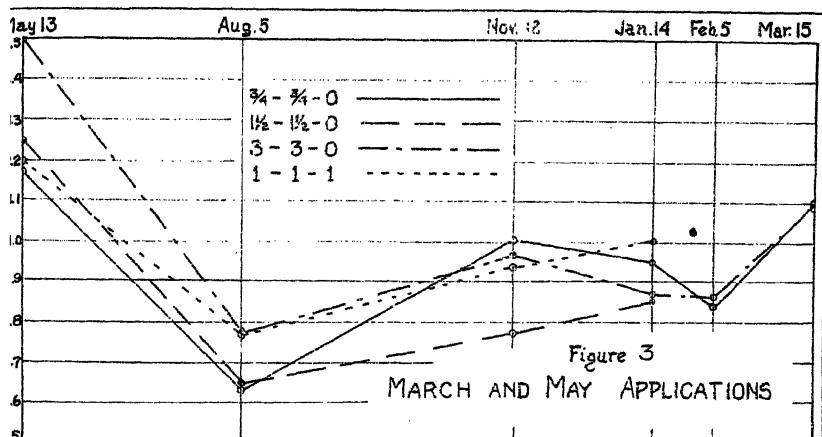


FIG. 2. Single applications of 3 pounds applied at different times.

In Fig. 5 for trees which received only the early application all treatments had about the same minimum in August. Apparently in this case the trees had established a balance between the amount of growth and the different rates of application made in the spring.

In considering the period after harvest, in general the differences in nitrogen content of shoots that existed in August between trees receiving different rates of applications at the same times, were maintained until November regardless of the different amounts applied after harvest. As different amounts of terminal growth were secured this would seem to indicate a balance between rate of growth and amount of nitrogen fertilization. Of the three comparisons of three each there are only two exceptions, namely, the $\frac{3}{4}$ -pound treatment in the March and May application and the 3-pound treatment of the May and August application. This is probably related to response in growth as in the former case the $\frac{3}{4}$ -pound treatment made less growth than the two plots with which it is compared, which may have made possible a greater accumulation. In the latter case, the 3-pound treatment made decidedly the greatest growth, which may have utilized much of the assimilated nitrogen without much change in percentage amount, although giving a greater absolute amount of nitrogen in the tree. In these two curves it is of interest that the one for the trees receiving $\frac{3}{4}$ pounds in Fig. 3 is similar to that for the $1\frac{1}{2}$ -pound trees in Fig. 4, and that in each case the amount applied before harvest was $1\frac{1}{2}$ pounds. Also that the curve for the 3-pound treatment in Fig. 4 is similar to that for the $1\frac{1}{2}$ -pound treatment in Fig. 3 where the total amount applied before harvest in each case was 3 pounds.

Where less than a total of $1\frac{1}{2}$ pounds of nitrate was applied before harvest, ($\frac{3}{4}$ -pound treatment, Fig. 3; $\frac{3}{4}$ - and $1\frac{1}{2}$ -pound treat-



FIGS. 3, 4, 5. Relation of total nitrogen to time and amount of fertilizer application.

ment, Figs. 4 and 5) or where the 3 pounds was applied in March with none in May (Fig. 5), the increase in percentage of total nitrogen in the shoots after harvest was more rapid than when the application was 3 pounds or more. This is apparently related to growth, as trees receiving only $1\frac{1}{2}$ pounds or less made an average terminal growth of about 24 inches, and trees receiving 3 pounds or more before harvest made an average terminal growth of 36 inches.

In the period between November and January it will be noticed from the graphs that the curves for the various treatments show a tendency to converge. This is better indicated in the following table giving the percentage of total nitrogen in the shoots for November and January, arranged in order of the amounts in November.

TABLE II—TENDENCY TO EQUILIBRIUM IN TOTAL NITROGEN DURING DORMANCY

Treatment Pounds of Nitrate Applied			Total Nitrogen in Shoots Percentage of Dry Weight		Change in Amount, Increase or Decrease
March	May	August	November	January	
0	0	3	1.156	1.100	Decrease
$\frac{3}{4}$	$\frac{3}{4}$	0	1.020	.956	Decrease
3	0	3	.999	.958	Decrease
$1\frac{1}{2}$	0	$1\frac{1}{2}$	.983	.996	Increase
3	3	0	.972	.870	Decrease
$\frac{3}{4}$	0	$\frac{3}{4}$	.960	1.132	Increase
0	$1\frac{1}{2}$	$1\frac{1}{2}$	.955	.931	Decrease
1	1	1	.937	1.015	Increase
3	0	0	.884	.953	Increase
0	3	0	.870	.890	Increase
0	$\frac{3}{4}$	$\frac{3}{4}$	.858	.861	Increase
$1\frac{1}{2}$	$1\frac{1}{2}$	0	.777	.849	Increase
0	3	3	.747	.942	Increase

With only two exceptions, where the percentage in November was .955 or more there was a decrease in January, and without exception where the percentage was less than this there was an increase in January. Moreover there is no apparent relation of these changes to nitrogen fertilization. A decrease in nitrogen in the shoots during this period must indicate a translocation to other parts of the tree, and an increase must indicate a movement of nitrogen into the shoots. This would suggest a tendency in the tree to come to a physiological equilibrium during the first weeks of the dormant period, and is probably associated with the relative concentration of nitrogen in the shoots and in the tree.

It is recognized that the shape of the curves given in these graphs is more or less determined by the dates of sampling, and that maximum and minimum points therefore may vary more or less from those indicated. A more thorough study at these times of the year might show that some of the differences between treatments is due to the time at which these physiological changes occur as well as to amounts of material.

Recent Developments in Citrus Coloring

By J. R. WINSTON, and J. M. LUTZ, *U. S. Department of Agriculture, Washington, D. C.*

CITRUS fruits often are mature while the skin is still partially or entirely green. To make the appearance of the fruit match its eating quality special means of coloring are widely adopted. By these coloring methods natural processes are assisted to cause the green chlorophyll to disappear and the orange or yellow pigments in the skin to become predominant. This treatment is of extreme importance to the industry since under some conditions it is only by such artificial means that a satisfactory color can be produced on fruit otherwise suitable for shipping.

The purpose of this paper is to present a summary of the results of recent investigations on factors influencing the rate of coloring and subsequent keeping quality of the fruit.

Temperature is probably the most important single factor in determining the rate of coloring. The best temperature for coloring without danger of injury to fruit is about 85 to 87 degrees F. Fruit temperatures above 95 degrees F. are liable to result in injury to the fruit. Fruit colors very slowly below 80 degrees F. On cold days fruit frequently colors as fast in the open air as in unheated or poorly heated coloring rooms. The rate of coloring is increased if the fruit is brought up to the optimum coloring range quickly. This can be accomplished by holding the air temperature at about 95 degrees F. until the fruit reaches a temperature of about 85 degrees F. and then maintaining an air temperature of 85 to 87 degrees F. Steam radiators or coils have generally been found to be the most desirable method of heating. In order to raise the temperature quickly, live steam is also used during the first 2 or 3 hours of the coloring period. This also prevents the humidity in the coloring room from going down too low while the temperature of the room is being raised.

During periods of warm weather, little or no heat is necessary. In fact, it is sometimes desirable to cool the coloring room. This can be accomplished to some extent by ventilation or by circulating the air through a water spray.

Since the rate of coloring is greatly modified by only a few degrees difference in temperature, it is essential to get every part of the coloring room, to the optimum temperature quickly. In the old type coloring rooms in which there is little or no air circulation, it is not unusual to find temperature differences of 30 degrees F. or more, between the top and bottom of fruit. Under these conditions the fruit at the bottom of the room is usually so cold that it colors very slowly while that at the top of the room is subjected to danger of heat injury. The small electric fans that are used in some coloring rooms are prac-

tically worthless. In a room of 1-carload capacity, a blower with an actual delivery of at least 2000 cubic feet of air per minute is desirable. In Florida good results are being obtained by using a blower with a 2-horsepower motor. The blower is run at high speed at the start in order to get all portions of the room at approximately the desired temperature, and then it is run at slow or moderate speed.

The most successful method of circulation is to have an air conditioning chamber located outside the coloring room, in which the air is brought to the desired temperature and humidity. Fresh air and ethylene are also introduced into this chamber. Practically all modern coloring rooms are thermostatically controlled. The conditioned air is forced from the chamber through ducts or against a spreading baffle at the top of the room. The air then passes downward through the fruit to a space between a false floor and a tight sub-floor. It is then drawn through a duct which is built against or within one of the side walls and leading to the conditioning chamber where it is again recirculated.

Adequate ventilation should be provided during the entire coloring period in order (1) to eliminate the carbon dioxide which is given off by the fruit, (2) to eliminate excessive humidity, and (3) to cool the room when necessary. There is also ample evidence that lack of ventilation promotes the development of stem-end rot. Ventilation can be secured by opening a vent on the suction side of the blower which permits the introduction of outside air. The size of the opening to be used will necessarily vary with the size and tightness of the room and the type and speed of the blower. Usually an opening of 3 to 8 square inches is adequate for a coloring room of 1-carload capacity. Too much fresh air is undesirable because it upsets the gas equilibrium and makes it more difficult to maintain proper temperatures and humidities.

There is some evidence that relative humidities below about 70 may diminish the rate of coloring while the fruit is in the coloring room or else "set" the color thus retarding further color development after removal from the coloring room. The most important role of humidity, however, is in its effect on the fruit. Low humidity may wilt or "age" the fruit. Brown patches may appear around the stem end of the fruit at low humidities. The latter is sometimes erroneously attributed to the coloring gas. Low humidities are especially dangerous when combined with high temperatures. Extremely high humidity is more conducive to decay development and tends to make the fruit lose its stems or "buttons." A relative humidity of from 80 to 92 seems to be the most desirable. The optimum humidity depends on several conditions, principally climatic conditions, fruit temperatures and the predisposition of the fruit to decay. The fruit should not be allowed to remain wet for over a few hours.

The humidity of a coloring room can be increased by the use of live steam or a fine water spray. This is generally introduced into the conditioning chamber. During cold weather the humidity of a color-

ing room can most effectively be lowered by raising the temperature of the room. In warm weather the problem is difficult. Ventilation is of some value in this connection. Ample circulation will aid in drying the fruit if it has become wet.

Ethylene gas is generally considered superior to kerosene fumes for coloring. Besides being cheaper, ethylene generally produces a better color in a shorter time. Kerosene fumes are unpleasant to work in and they often impart an unpleasant flavor to the fruit. The use of kerosene fumes also results in a greater fire hazard.

Practically all modern coloring rooms in Florida are now equipped with the "trickle system" of coloring. The principle of this system is that a small constant supply of ethylene is continuously introduced into the room. The introduction and regulation of the gas is usually accomplished by two reducing valves attached to the high pressure cylinder in which it is purchased. The gas pressure is usually reduced to a fraction of a pound and is conducted through a quarter-inch main-line pipe with laterals leading into the air conditioning chamber of each coloring room. At the discharge end of each lateral pipe there is a nozzle with a cut-off to enable one to turn the gas on or off from a given room without affecting the operation of other rooms. The gas is turned on when the room is filled with fruit and is left on until the coloring is completed. Although the pressure in the ethylene cylinder may vary considerably, the pressure on the line remains constant. The rate of gas flow can be changed by simply changing the pressure on the line. Ethylene is most satisfactorily used at a rate of about 3 to 4 cubic feet per day in a room with 1-carload capacity.

The manner in which fruit responds to coloring treatment depends very largely upon its innate qualities. A thin skinned, fine-textured fruit such as the Pineapple orange grown on rather heavy soil is more easily colored than coarse-textured fruit of the same variety grown on poor soil. Sour orange stock usually produces fruit of better color than that grown on rough lemon stock. A well fertilized tree which has had sufficient potash and superphosphate without an excess of nitrogen produces fruit that assumes a richer and deeper color than fruit from starved trees or from trees with rank green foliage developed by fertilizing principally with nitrogen.

Since 1929, the length of time necessary to produce good color on fruit has been materially reduced in Florida. In some cases it has been cut in half. Under improved methods it rarely requires longer than 60 hours to color green or nearly green oranges at the first of the season. Later in the season it may require only 36 hours or less. It requires somewhat longer to color regreening Valencias in the spring. The time required to color grapefruit is usually from 12 to 24 hours less than that necessary for oranges.

The high temperature of coloring rooms is not only conducive to rapid aging and wilting of fruit but it is also ideal for the development of stem-end rot. For these reasons it is imperative that fruit be colored and placed in an environment such as a precooling room as

quickly as possible. Sometimes when some fruit in a coloring room colors faster than others, there is a tendency to pack the fully colored fruit and sort out the greenish fruit and return it to the coloring room. This recolored fruit, because of its long exposure to coloring room temperatures develops heavy decay and if paraffin has been applied before the fruit is returned to the coloring room, it not only fails to color properly but is also likely to scald. Rapid coloring also cuts down the operating cost and increases the coloring room output.

Light and Pigment Development in Apples

By L. R. STREETER, and G. W. PEARCE, *Experiment Station,
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INVESTIGATIONS have been carried out in recent years in an attempt to improve the color of various fruits. Bananas, tomatoes, cranberries, and citrus fruits, in particular, have received the most attention. Several studies of the factors influencing the formation of the red pigment of apples have been made. In general, these have included the influence of light, fertilization, pruning, artificial tree and fruit feeding, and a few preliminary observations on the use of ethylene gas to improve color.

Overholser (1) has shown that light is one of the most important factors in the development of anthocyanin pigments, not only in the apple but in other kinds of fruit as well, such as pears, peaches, plums, nectarines, etc. Magness (2) has presented data which indicate that apples must reach a certain state of maturity before red color will develop on exposure to light. In other words, certain substances must be present in the fruit before the anthocyanin pigment can be produced by the action of light.

Since light is such an important factor in anthocyanin formation it becomes essential to determine which wave-lengths of light are most influential. In a previous paper by Pearce and Streeter (3) a report was given on the effect of various wave-lengths of light on development of color in McIntosh apples. This paper deals with the results obtained by the use of light filters, and preliminary studies on the influence of artificial light on color formation in McIntosh apples.

It is common observation that the sides of McIntosh apples exposed to the direct rays of the sun are always more highly colored than the sides away from the sun. Picking fruit and removing it from the sun stops the development of red color. In the absence of light, mature green apples will lose their green color and become yellowish. This process is no doubt nothing more than the disappearance of chlorophyll with the consequent appearance of the yellow pigments which were masked by the green color. Similar observations have been reported by other workers in regard to other varieties of apples which develop red pigments. It has been observed that those parts of the apple which have been shaded by leaves or heavy spray deposits are never colored red, but on exposure to sunlight the red pigment is developed. This indicates that neither the parent substance nor the final red pigment is readily diffusible between various cells.

McIntosh apples selected for use in this experiment were mature but had only traces of red color development. The amount of color developed was estimated on the basis of the percentage of the apple surface colored.

In the experiments in which artificial lamps were used as a light source, no filters were employed. In a few preliminary experiments with an ultra-violet lamp no definite coloration was detected in any case, and severe injury to the flesh and skin of the apple resulted. The fruit became pitted and was discolored at the points of indentation. Magness (2) reports color development of Jonathan apples by exposure to an ultra-violet lamp. Arthur (4) has found that McIntosh apples color well under the influence of an ultra-violet lamp, when placed at sufficient distance from the lamp to avoid injury from ultra violet and infra red rays.

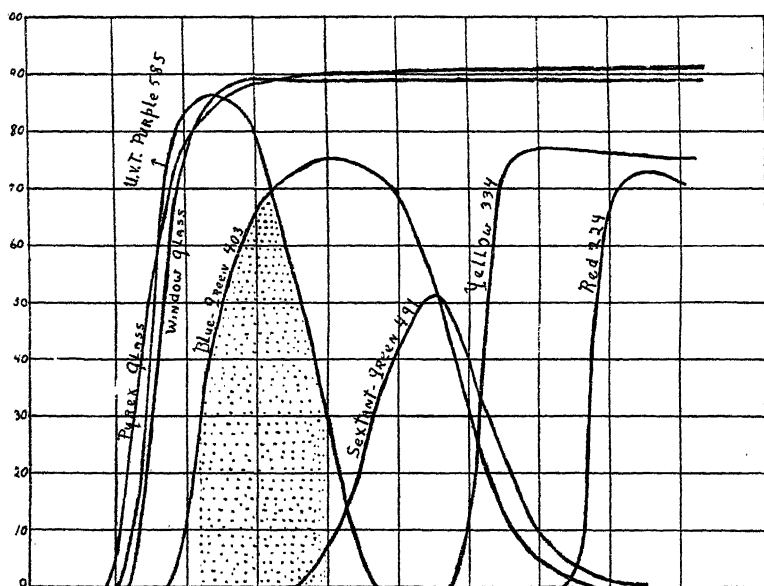


FIG. 1. Transmission of light by the filters employed. The per cent of transmission (ordinate) is plotted against the wave-length in Ångström units (abscissa). All curves except the one marked "window glass" were reproduced by permission of Director G. K. Burgess of the Bureau of Standards from Gilson, K. S., Tyndall, E. P. T., and McNicholas, H. J., *Bureau of Standards Tech. Paper No. 148* (1920). The curve for window glass was reproduced by permission of M. Luckiesh from his book "Artificial Sunlight," (3) p. 110, Fig. 25.

McIntosh apples were exposed to sun light during October and November. Colored glass filters were employed which were designed to transmit only certain parts of the spectrum. Table I gives a brief summary of the results.

Fig. 1 brings out more clearly the influence of the various portions of the spectrum. Filters 403, 585, Pyrex, and window glass produced a large amount of color, while those that produced prac-

tically no pigmentation were Filters 334, 224, 491 and H. T. From Fig. 1 it is observed that those glasses under which coloration developed have a transmission range of from 3000 to 7000 + Å. Those under which little color developed have a range of from 4400 to 7000 + Å. This indicates that the effective range is below 4400 Å.

It has been assumed that the reason for lack of pigment formation in the case of glass Filter 491 is the absence of the effective wavelengths of light. This may not be the case because the curve for this glass in Fig. 1 shows only 50 per cent transmission at its maximum point, while the region from 4300 to 4800 Å. is transmitted much less intensively. This would place the upper limit of the effective range at 4800 Å. It now remains to establish a lower limit, and it is readily seen to be at approximately 3200 Å., because both the Pyrex and window glass produced good coloration.

TABLE I—EFFECT OF LIGHT OF DIFFERENT WAVE-LENGTHS ON COLOR DEVELOPMENT

Code No. ¹	Glass Filters Used	Range of Transmission	Coloration in 7 Days ²
	Description		
		Å.	per cent
Check	Direct sunlight.....		85
Check	Window glass.....	3200+7000+	70
Check	Pyrex glass.....	3100—7000+	70
H. T. Check	Opaque heat-transmitting glass.....	Infra red	2
403	Blue-green, medium shade.....	3500—6000	50
585	Ultra-violet-transmitting blue-purple	3000—4800	50
224	Red.....	6200—7000+	5
334	Heat-resisting yellow special shade...	5400—7000+	10
491	Sextant green.....	4400—6800	3

¹Code numbers are those of the Corning Glass Works, makers of the colored glass filters.

²Apples had from 1 to 4 per cent coloration before exposure.

This range may be still further limited by a comparison of the two Filters 403 and 585. Table I shows that both filters produced the same amount of color. From a study of their transmission curves in Fig. 1 it is noted that they overlap each other. Since both produced the same extent of color, it is evident that the point at which their transmission curves intersect marks the approximate wave-length of influence. Likewise, the region bounded by the intercepts of the two curves marks the influential range of the spectrum. This region is shown as the dotted section of Fig. 1. Thus, we have established a range of from 3600 to 4500 Å., with an optimum at 4100 Å., as the most effective part of the solar spectrum during October and November on anthocyanin development in the McIntosh apple.

The results of the foregoing experiments suggested the possibility of using an electric lamp of high intensity in the effective wave length range. A 1500-watt Mazda lamp with a suitable reflector was selected as a good source of light of the required wave length. Apples were exposed to the light in a cabinet that could be cooled sufficiently to keep them in good condition. The lamp was placed outside and above

the cabinet. The light was filtered through 1-inch of running water to remove excess heat. Water was circulated through a pan with $\frac{1}{4}$ -inch plate glass bottom which formed the top of the cabinet. Apples were placed at a distance of 3 feet from the lamp.

Upon continuous exposure for 5 or 6 days apples that showed no red color became almost completely colored. The first traces of color began to appear as streaks of red after 60 to 70 hours exposure. The color continued to develop for about 3 days more after which no further increase in color was detectable. Apples exposed to cloudless sunlight in October and November seldom show signs of color development until the end of the second day or about 16 hours of light exposure. Apples held in cellar storage at 45 degrees F. for 3 months responded to light and developed color, although they did not become as intensely colored as apples treated soon after picking.

While the use of artificial light offers little possibility as a commercial means of coloring apples, it is a useful method for studying light as a factor in pigment formation.

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Effect of Selection Within Apogamic and Clonal Progenies

By H. J. WEBBER, *Citrus Experiment Station, Riverside, Calif.*

IN a paper presented before this Association on "The Economic Importance of Apogamy in Citrus and *Mangifera*" (5), it was pointed out that "By the elimination of the variants from seedling progenies of individual trees of those species or varieties that develop a high percentage of apogamy, there is obtained a population almost wholly of apogamic origin and nearly or wholly uniform in genetic constitution." Such progenies are comparable to clonal progenies and apparently give like reactions. Investigations in the use of monoparental¹ apogamic and clonal progenies have advanced to the stage where it is important to question whether any improvement can be made by the selection of the largest and best individuals within such progenies.

The genetic investigations of Johanssen (3) and many others on selection within "pure lines", where apparently no significant advance has been obtained unless there occurred a change of type (mutation), do not give much promise of important improvements being secured by selection within a clone. The investigations on this problem, however, so far as the writer is informed, have been directed wholly toward the discovery of whether a change could be induced that would have genetic significance. It would seem to the writer to be entirely reasonable to assume that the selection of the largest individuals within an apogamic or clonal population might result in a distinct improvement in quantity of crop produced during all or a part of the life of the selected trees and yet not indicate any change of type that could be considered of genetic importance.

Apogamy in Citrus has provided a means of easily and cheaply producing large numbers of seedlings of like genetic constitution, but, nevertheless, such seedlings in all cases exhibit a considerable range of variation in size.

In the writer's experiments on Citrus stocks, progenies of from 100 to 200 or more seedlings each have been grown from seeds of selected good trees of several species and varieties. In each of these progenies the smallest seedlings to the extent of about 10 per cent were discarded at the seed bed, which probably resulted in the elimination of a considerable proportion of the sexually produced seedlings. At the time of budding, also, all of the "off-type" and undersized seedlings were eliminated so that all clearly distinguishable variants were discarded from each progeny. The range of variation in size among the remaining seedlings of different progenies when they were 3 years old, as shown by the area of cross section of trunk 4 inches above the soil, gave the following

¹Monoparental,—meaning from one individual parent which may be either a seedling or a clone.

coefficients of variation for the different species: sweet orange, 35.72 ± 1.95 to 40.22 ± 2.27 ; sour orange, 26.89 ± 1.37 to 28.76 ± 1.09 ; and grapefruit, 63.41 ± 3.74 to 76.98 ± 4.67 . This range of variation in size may be partially due to genetic variation, as some few sexually produced seedlings doubtless remained in each progeny, but as much the largest proportion of the seedlings remaining were certainly from apogamic embryos, the variation, it would seem, must be mainly due to various environmental causes, or perhaps to incidental differences in size among the embryos.

Two citrange varieties, the Cunningham and Savage (normally 100 per cent apogamic), gave coefficients of variation respectively of $23.94 \pm .931$ and $26.65 \pm .892$, proving, as might be expected, to be less variable than varieties exhibiting a lesser degree of apogamy. Opposed to this interpretation, however, is the fact that the Sampson Tangelo (100 per cent apogamic) gave a variation coefficient of 91.03 ± 6.08 indicating the widest range in seedling size at this young age of any progeny of seedlings studied. As these three varieties are known rather certainly to produce only apogamic seedlings under the conditions thus far studied, the difference in the range of variation exhibited seems rather surprising since it apparently is to be considered as variation within a monoparental genetic type. The rough lemon, a widely used stock supposedly of hybrid origin, from which as high as 96 per cent of the embryos have been found to be of apogamic origin, gave a coefficient of variation in one progeny containing 186 seedlings of 33.58 ± 1.30 and in another progeny of 118 seedlings 90.23 ± 6.42 . In these two progenies grown at different times from seed of the same tree it would seem that the different range of variation must be due to environmental causes and this is, of course, entirely possible.

With this great range in percentage of variation due probably in part to variations in original size of embryo, in part to promptness in starting growth, and in part to numerous environmental causes, and supposedly not to genetic differences, the question is vital as to whether the selection of the largest and most vigorous seedlings will prove to be important in the production of good groves.

During the last 12 years the writer has had experiments under way designed to test the comparative effect of using different sized citrus seedlings as rootstocks. It has been found that within comparatively homogeneous apogamic seedling progenies, the large seedlings in general produce somewhat larger budlings than the small seedlings of the same progeny, and that this larger size of the budlings is maintained in the orchard for at least several years. Trees on large seedling stocks during the first 8 and 10 year periods in the orchard have yielded over 19 per cent more than comparative trees on small seedling stocks from the same apogamic progeny. These results were described in some detail in a paper presented by the writer (4) at the 1930 meeting of this Association.

The evidence indicates that the difference in size and yield of Citrus trees on large and small seedlings, which during the first few years is quite marked, gradually disappears in later years. How long an appreciable difference will be maintained cannot at this time be determined. It is apparent, however, that some difference remains up to the close of the eighth year in the orchard.

The writer has had no experiments in the selection of large and small plants from progenies propagated by cuttings or slips (clonal progenies), but selections based on size from such progenies should apparently react the same as selections from purely apogamic progenies. Evidence confirming this is furnished by the results obtained by Bioletti (1) in an experiment in testing the effect of size and quality of rootings (rooted cuttings) of the grape. The influence of size of cutting was very marked during the first three seasons in the vineyard, was noticeable in the fourth year, but had largely disappeared by the end of the fifth year. Bioletti states "The first crop of the vines from the strongest 25 per cent of the rootings was about 50 per cent larger than the first crop of the vines from the weakest 25 per cent. This difference was in great part reversed by the second crop and there was little difference in the third crop.

"The advantage of the strongest rootings was in reaching full bearing the third season instead of the fourth as with the weaker rootings. The poorest rootings (used in this experiment) were all equal to what one usually considers No. 1 quality. With more imperfect rootings such as are very commonly planted, the difference would undoubtedly have been greater."

The practical advantage to be derived from a severe selection of cuttings in this case is indicated by Bioletti's statement that "The best rootings (row 2) therefore yielded a crop of over 3 tons to the acre more than the fair rootings (row 16). The value of the extra crop was much greater than the total cost of the best rootings."

From the data that has thus far been obtained it would seem that it may be concluded that selections from clonal progenies are likely to react the same as similar selections from monoparental apogamic progenies or vice versa.

It seems to the writer, from the evidence that has come under his observation, that at least in some cases there is clearly marked influence from the use of large or small seedlings or cuttings from apogamic and clonal progenies that is effective during a considerable portion of the life cycle of the plant. In grape cuttings this influence was clearly marked up to the third year when the vines were in full bearing and in Citrus the influence was observable up to at least the end of the eighth year in the orchard. In both grapes and Citrus the influence on yield in the early years effected by choosing large plants was apparently sufficient to justify a severe selection.

It is not likely that any result obtained by selection in such cases as these can be considered as in any way affecting the heritage

of the plants. The result is interpreted by the writer as being due entirely to the hold-over influence of large size and vigor in the young seedlings or cuttings which maintain the advantage gained during a considerable portion of the life of the plant. In long-lived, slow-growing perennials such as *Citrus* this advantage may be maintained for a considerable number of years.

If we could choose two seedlings, one large and one small, which had inherited exactly the same growth rate and could plant these in absolutely uniform soils and under entirely uniform conditions so that the growth of each would be equal, theoretically the small plant could not reach the size of the large plant until a stage of senility was reached where the rate of decay equaled the rate of growth. Such theoretically uniform conditions, of course, can never be attained in practice but it seems reasonable to assume that the varying influences that affect the large seedlings would have equal influence on the small seedlings so that in general the average difference would be maintained.

The only question is whether the relatively small difference in size between the small seedlings or cuttings and the large ones when they are young is great enough to influence the resulting plants during a sufficiently long time to be of practical importance and justify the expense of making a selection. With *Citrus* seedlings that are to be used as rootstocks the writer's experiments seem to answer this question in the affirmative and the same is true of Bioletti's experiments with grape cuttings.

Attention may be called to the fact that this result in effect is comparable to that obtained in selecting large and small seeds of various plants and is in conformity with Blackman's (1919) findings relative to the compound interest law as applied to the rate of plant growth.

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The Economic Importance of Apogamy in Citrus and Mangifera

By H. J. WEBBER, *Citrus Experiment Station, Riverside, Calif.*

THE purpose of this paper is not to present new facts relative to apogamy in the genera Citrus and Mangifera, the orange and the mango, but to call the attention of horticulturists to the important economic role which this interesting natural phenomenon plays in two horticultural industries, and to the problems involved.

Certain plants, seemingly not being content to risk their existence on the precarious possibilities of sexual reproduction alone, have evolved the ability, through means of the phenomenon termed apogamy, to produce viable embryos in the seed which have no direct relation to the regular egg apparatus and fecundation.

This is accomplished, as we know through the investigations of Strasburger (3) and others, by the specialization of certain cells or groups of cells in the body of the ovary (nucellus) of the mother near the wall of the embryo sac. These cells become highly protoplasmic, grow and divide more rapidly than the neighboring cells, and finally form masses of tissue which push out into the embryo sac and form embryos so nearly like those which develop from the egg cells proper that the two types of embryos cannot be distinguished one from the other in the seed.

Since apogamic embryos, originate from the somatic tissue of the mother and are not preceded by reduction division and fecundation they naturally carry the full diploid chromosome complement direct from the mother and transmit the same heritage as the mother type. It would be expected, thus, that they would reproduce seedlings of the same type as the mother unless there occurs some irregularity in an occasional cell division and such irregularities are not common.

While the seeds of both Citrus and Mangifera contain (except very rarely) only one egg cell and thus one sexually developed embryo, this apogamic development leads usually to the formation of several embryos in each seed (polyembryony), all of which are apogamic in origin except that one which comes from the egg cell following fecundation. It is also an important phenomenon that apparently this one sexual embryo is frequently crowded out or for some cause fails to develop in which case all of the embryos of a seed are apogamic.

In 1900 the writer (5) pointed out the difficulties that this phenomenon introduced into the study of Citrus hybrids, where a large percentage of the seedlings that develop from carefully crossed and guarded flowers are of apogamic origin. Here the seedlings from apogamic embryos cannot be distinguished readily in early stages from the true hybrids unless the parents differed markedly in some character which, combined in the hybrid, results in a dis-

inctive character of foliage that enables the hybrids to be recognized. In hybrids of parents with similar foliage and plant body characters the true hybrids cannot be distinguished with certainty until they bear fruit, thus necessitating the expense of growing large numbers to secure a few hybrids. Here apogamy is a distinct disadvantage.

In Citrus the main value of apogamy is likely to be found in its relation to the problem of securing rootstocks of uniform character. During the last 10 years attention has been focused on the very great importance of the character of the rootstocks used in horticultural propagations and it has become increasingly evident that the genetic variation in seedlings used as stocks is to be considered as responsible for much of the variation in the size and production exhibited by orchard trees. The great desideratum, thus, in the propagation of Citrus, as is the case also with other orchard fruits, is the availability of rootstocks that are known to possess the same heritage and to react the same under the same environmental conditions with a given scion variety.

To obtain such uniform rootstocks experimentation has been directed toward vegetative propagation by cuttings or layers of known types of stocks and the comparison of the results produced by stocks thus obtained with the results obtained when the more or less variable seedlings from the same type are used. This work, mainly introduced and stimulated through the investigations of Director Hatton (2) and his co-workers (1917 and later) at the East Malling Research Station, England, on the vegetative propagation of deciduous fruit stocks, has been taken up recently by many of our American Experiment Stations. In Citrus culture the propagation of fruit varieties by cuttings and layers has in some cases been successfully practiced (8), but the propagation by such methods of rootstocks which must later be budded has not been used in a commercial way. It seems probable that if such methods are to be used in Citrus it will be to grow fruit varieties direct from cuttings, on their own stocks, rather than to propagate stocks for budding.

In the studies of Citrus rootstocks, which are being conducted by the writer, it was early recognized that apogamy was likely to exercise an important role as it was known that several of the stocks commonly used exhibited a high degree of apogamic development. The early studies of the writer (6, 7) and the more recent investigations of Frost (1) and of Toxopeus (4) have indicated the variation in the percentage of apogamic embryos in some of the Citrus species and varieties commonly used as stocks to be approximately as shown in Table I.

This wide variation in the percentage of apogamy shown by different varieties or races of the same species must be of significance in the production of uniform progeny and thus in the adaptability of the different sorts for use as stocks.

A factor of exceptional interest in this connection is the high percentage of apogamy exhibited by some F_1 hybrids of radically distinct species and the fact that such hybrids are frequently exceptionally vigorous and are likely to possess value as stocks. The trifoliolate orange (72 per cent apogamic) crossed with the sweet orange (40 to 95 per cent apogamic) gave rise to the group of F_1 hybrids which have been designated "Citranges" (7), and some of these have already attracted attention as desirable stock types. Progenies of several hundred plants each of several of these hybrid varieties, namely, Savage, Cunningham, Morton, Coleman, and

TABLE I—RANGE OF APOGAMY IN SPECIES OF CITRUS

Species	Range in Percentage of Apogamic Embryos
Sweet orange varieties (<i>C. sinensis</i>)	40 to 95
Sour orange varieties (<i>C. aurantium</i>)	75 to 85
Grapefruit varieties (<i>C. grandis</i>)	60 to 95
Mandarin orange varieties (<i>C. nobilis</i>)	10 to 100
Lemon varieties (<i>C. limonia</i>)	10 to 96
Citron varieties (<i>C. medica</i>)	40 to 50
Trifoliolate orange (<i>Poncirus trifoliata</i>)	72

Rusk, have been grown in connection with the writer's experiments and were found on careful examination of 3-year-old seedlings to have reproduced apparently true to the variety type in all cases. The seedlings of these varieties are therefore to be considered as being approximately 100 per cent apogamic. Attention should be called to the fact that one of these Citranges, the Sanford, apparently develops few if any apogamic embryos and has been found to break up into many types in the F_2 generation.

A high percentage of apogamy is also exhibited by the Sampson Tangelo (Grapefruit X Tangerine) where the F_2 seedlings produce trees of the same character as the original F_1 hybrid. Twenty-eight F_2 seedlings of the Sampson Tangelo when about 2 years old chosen at random merely as good vigorous plants were planted in the Variety orchard of the Citrus Experimental Station in 1917. They are now about 16 years old and are growing in the same field adjacent to several budded trees of the F_1 hybrid variety affording thus an opportunity for an easy comparison of their characters with those of the mother type. The F_2 seedlings are remarkable for the uniformity they exhibit *inter se* in size, branch, foliage, and fruit characters, and for their vigorous growth. They can be distinguished from the F_1 budded trees only by their more upright growth which is a character almost invariably exhibited by seedlings as distinct from budded trees. The examination of a population of over 200 3-year-old seedlings also showed only typical foliage characters of the variety (F_1 hybrid characters) and it is thus clear that the seedlings of the Sampson Tangelo under ordinary conditions are probably 100 per cent apogamic.

It would seem from what has been stated above as to the high percentage of apogamy occurring in many types of Citrus, that the obtaining of seedlings of uniform genetic constitution for use as rootstocks would present little difficulty, although there is, in most cases, a small number of the sexually produced embryos that develop seedlings.

In the writer's experiments it has been found that among the progenies of all species and varieties that are not completely apogamic there occurs a small proportion of seedlings that differ from the prevailing type of the progeny in character of branching, foliage, and fruit. Most commonly these variants are of comparatively small size though some are not, and almost invariably they produce some degree of dwarfing in scions grown on them. The evidence available indicates that these variants apparently are seedlings produced from the normal (sexual) embryos, probably mainly by self-fertilization. The roguing out of these variants from a batch of nursery seedlings before they are budded is the most important selection that can be made in the nursery. The seedlings remaining after such an elimination can be safely considered to be chiefly of apogamic origin.

By the elimination of the variants from seedling progenies of individual trees of those species or varieties that develop a high percentage of apogamy, there is obtained a population almost wholly of apogamic origin and nearly or wholly uniform in genetic constitution. Such seedlings, if all from the same tree or clone, should possess the same degree of congeniality with the scions of any given fruit variety worked on them by budding or grafting; and the reactions produced under a given set of conditions can be determined sufficiently accurately so that apparently the same result can be confidently predicted whenever the same combinations are used under the same set of conditions.

Probably no such certainty of results could ever be obtained by the use of variable seedlings of differing genetic constitution such as those obtained from cross pollinated plants that develop seeds in the normal way from the fertilized egg cells only. Apogamy thus apparently furnishes the citrus nurseryman a means of obtaining easily from any known good stock type, large batches of seedlings that can be depended upon to be of nearly uniform genetic type and to give a uniform reaction on the scion. This result has apparently been of great value to the industry in the past although not generally recognized and is likely to be of greater importance in the future as we learn more about the conditions and the reactions to be expected.

In mangos (*Mangifera indica*) it has been long known that certain groups are apogamic and develop several embryos to the seed. In the Peach Mango grown in the Transvaal the writer found by counts in a nursery that each seed gave an average of $2 \frac{1}{3}$ seedlings. This variety is extensively grown in South Africa and is regularly propagated by seeds without grafting. The examination

of about 300 fruiting trees of this variety indicated that as great uniformity existed in the fruits as would be expected among fruits on asexually propagated trees. It seems evident that in this variety the degree of apogamy can be considered as approximately 100 per cent and that the variety can be as safely propagated by seeds as by budding or grafting.

The Saber mango, a variety also grown in South Africa, is commonly grown from seeds and apparently comes true to the type of the variety. It is probable that in this case also almost all of the seedlings come from apogamic embryos.

In sections of the tropics certain good mangos have been commonly propagated by seeds, but vegetative propagation is mainly advocated. Seedlings can be grown more cheaply than vegetatively propagated trees, and those good varieties that are highly apogamic certainly should be tested comparatively by both methods of propagation.

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Hybridity in the Genus *Lilium*

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IN spite of the oft-repeated pessimistic views that hybrids in lilies are few and far between and when made are difficult to hold, important progress is being made in the production of lily hybrids of a superior quality. New light is being secured on the possibilities. It is now known that there is no more inherent weakness in a lily hybrid than in a hybrid of any other group. Indeed, it is sufficiently proved that some hybrids of related species and crosses between what are considered varieties of a species have greatly increased vigor. Not all the hybrids are strong but plenty of them are, probably as large a proportion as of any other group.

Of course it must be understood that the making of a hybrid or even getting it to flower is less than half the task; after that comes the long grind of working up a stock. Little is accomplished by producing a new lily and sticking it away in one's garden whence it eventually must disappear. The one good seedling must be multiplied by vegetative means into a large stock and placed in the hands of many growers to insure perpetuation. When this is done, the perpetuation is reasonably assured if the variety is worthy.

It is a peculiar thing, that in the lily to a much greater extent than any other group, horticulturists have violated the principles governing the propagation of a variety. All the stock of a variety of tulips or daffodils is patiently multiplied by vegetative means from a single seedling, it taking 20 years to develop a commercial stock of a daffodil seedling. However, in the lily there is a tendency to treat the descendants of an entire hybrid progeny as constituting a variety. In one case at least all the plants of two crosses made several years apart have been referred to the same variety. One may purchase seed of Sulphurgale and Backhouse hybrids which can not help being a disappointment.

Probably the reason for such a condition of affairs and such practices lies in the far greater percentage of desirable seedlings in a hybrid progeny of lilies than in most other groups. A hybrid progeny of 200 seedlings in some *Lilium* crosses may contain 200 more or less distinct plants, most of which are worthy of anyone's garden. Many may be too similar to justify their recognition as varieties but nearly all may be good lilies.

The prospective lily breeder above all things desires to know the vulnerable spots in the genus. He wants to know at what points an attack may be made with reasonable promise of success. There are certain classical examples well brought out in the literature and more may be added on the basis of recent work.

1. The Nankeen is a hybrid of *Lilium candidum* and *L. chalcedonicum*. This cross and its reciprocal should be made again with a

resulting large progeny from which to make selections. It was made once and White Knight produced, but that has been lost.

2. Parkman's lily was produced by crossing *Lilium auratum* and *L. speciosum*. It, too, has been lost. There is no question but this is a promising line of attack, but it is neither for the faint-hearted nor for the impatient. We will return to this later.

3. *Lilium umbellatum* in a host of forms is the product of *L. elegans*, *L. croceum*, *L. davuricum*, etc.

4. Dr. Walter Van Fleet crossed all his stock of *Lilium tenuifolium* and *L. concolor* both ways for three years. One hybrid out of more than 2,000 plants was secured, but a mole destroyed that. This loss should not be charged to any shortcoming of the lily, and the cross should be tried again.

5. *Lilium pardalinum* and *L. humboldti* cross readily and give a riot of color and strong, vigorous plants. Indeed, at least some of the commercial stocks sold today as *L. bloomerianum* seem to be of this derivation.

6. Both *Lilium pardalinum* and *L. humboldti* cross readily with *L. parryi*, giving most interesting hybrids.

7. *Lilium columbianum* crosses readily with *L. pardalinum*, and the F_1 progeny shows all gradations of inflorescence and bulb characters.

8. *Lilium regale* on *L. sargentiae* has produced the interesting hybrid, George C. Creelman. This cross should be made again in reciprocal, and a large colony produced from which selections of various types can be made. A recent letter from Professor Crow indicates this is being followed up.

9. *Lilium leucanthum* and *L. regale* cross readily, producing vigorous, robust hybrids which flower profusely the second year under entirely out-of-door conditions at the United States Bellingham Bulb Station, Bellingham, Washington.

10. *Lilium leucanthum* and *L. sargentiae* cross readily and some of the plants produce bulbils, with *L. leucanthum* as the female parent.

11. George C. Creelman on *Lilium leucanthum* has given bulbil-producing progeny. This cross proved to be two hybrids, as the bulbils can only come from the mother of Creelman.

12. *Lilium martagon album* will set seed with pollen of our West-American martagons as well as *L. tenuifolium*.

13. *Lilium hansonii* has steadily failed with us to set seed with its own pollen, but sets readily with that of *L. martagon* or its hybrids.

14. Miss Preston has produced *Lilium dærmottiae* (*L. willmottiae* crossed with *L. davidi*), and it is pronounced a desirable hybrid by those who have seen it. She is also responsible for *L. tigrinax* (*L. maximowiczii* on *L. tigrinum*), which is of undoubted value.

15. *Lilium martagon album* and *L. tenuifolium* have produced *L. tenuifolium*, Golden Gleam.

16. From Skinner's Dropmore Nursery in bleak Manitoba comes *Lilium scottii*, a cross of *L. willmottiae* with *L. mahonia*.

17. From Theodore Albert comes the announcement that he has an undoubted cross from *Lilium tenuifolium* on *L. regale*. After this, anything is possible.

This by no means exhausts the subject, but enough points of attack are enumerated to demonstrate the rich field that lies before the investigator who is inclined to do a piece of real investigational work for the benefit of the gardening public.

A line of attack which has a distinct appeal to the author has for its aim the production of a glorified regal flower similar to that of Creelman on a plant producing bulbils. This is a demonstrated possibility. Bulbil-producing plants have been secured from George C. Creelman \times *L. leucanthum*. It has a regal-like flower. A desirable hybrid of this kind could readily be reproduced vegetatively. *L. sargentiae* \times *L. leucanthum* has given a good percentage of bulbil-producing plants in the first generation. Our progenies in which *L. sulphureum* has been used are not yet far enough advanced to make definite predictions regarding them, but Sulphurgale hybrids are in commerce, and Professor Crow has carried the work farther.

It is interesting that so many of these hybrids are of recent origin. Most of them are too recent for stocks to be on the market. It is a remarkable showing when one considers that even in recent years it was stoutly maintained by some of the leading students of the lily that "It could not be done," the opinion being founded on the fact that it had not been effectively done in the past, the hybrids which had been made having mostly disappeared, supposedly because of weakness, when, as a matter of fact, as now appears, it was due to lack of commercial acumen or interest to work up stocks for a distribution wide enough to insure perpetuation.

No one can predict now what turn matters will take. Each breeder has his own ideas and is working to a certain end with certain species which seem to him to have the greatest promise. Some are working in a hit and miss fashion, crossing whatever varieties come into blossom together. This is decidedly desirable at the present time when the subject is new and the possibilities are so little known. A great deal of information will be gained in this way. A word of caution, however, may not be amiss. A failure in effecting a cross from pollinations may not prove that another trial will not succeed. Dr. Van Fleet's experience with *Lilium concolor* and *L. tenuifolium* is to the point. It took three reciprocal sets of crosses of his entire stock to produce a single hybrid seedling, and that was a vigorous "mule."

Wilson (1) recognizes a total of about 10 hybrid lilies, 4 of which we know no longer exist. Besides these he recognizes a possible hybridity in the *Lilium davuricum-elegans-umbellatum-thunbergianum* melange which may never be deciphered or even fully demonstrated. This is certainly a poor showing for so long a period as the lily has been known, and in a measure justifies the pessimism regarding the possibility of improving the species by cross pollination. Adding to these few recognized by Wilson, two or three others and the so-called

Backhouse hybrids, we have all the hybrid lilies developed up to about 15 years ago. Indeed, what is called *Princeps* belongs to the modern era, for it appeared about the time Wilson published his book. So there were no more than 7 or 8 hybrid lilies extant from all efforts made in that direction up to about 1920 unless we count all the *umbellatums*, and Backhouse hybrids which are comparatively modern.

So far as known, Luther Burbank was the first to point out the possibility of improvement by hybridity in our West-coast lilies. He actually produced "a riot of color and form," but so far as known did not get to the point of segregating out and developing clons from the seedlings thus produced. His work seems to have been entirely lost.

Each breeder has his own line of attack for the future and is the best qualified to discuss the probabilities in his groups. To the author there are two or three very promising leads, on each of which progress has been made.

I. *Lilium humboldti-pardalinum-parryi*. From combinations of these have come in the first generation 10 good lilies, half of which are now widely distributed in the hands of lily growers who will be able to offer a little stock to the public in 1933. These are Shuksan, Kulshan, Douglas Ingram, Star of Oregon, and Sacajawea. What is apparently the reciprocal of the cross which produced the five named above has produced a beautiful lily which is frequent in gardens of the lower Willamette Valley.

The second generation, obtained by promiscuous pollinations of the above among themselves, has yielded 10 more seedlings which were segregated in 1931 and the production of clons started. In this generation there are lilies ranging in color from pure lemon yellow through orange to those which are so dark brown they are almost black, a wider range than in the first generation.

At present three dozen definite crosses between the best of the first generation clons and between them and their parents are being grown. These began to blossom in 1931 and show still different colors and larger flowers. It seems safe to predict that 30 good and distinct lilies will come out of this line of hybrids.

II. *Lilium regale-sargentiae-leucanthum-sulphureum*. These species will combine readily in any way one chooses to apply pollen and in my opinion will be productive of some of the grandest of lilies. George C. Creelman is a glorified *L. regale*, a wonderful lily. Some recent crosses of it, *regale*, *sargentiae* and *leucanthum*, have produced some of the softest, most wonderful tints we have ever seen in lilies. The blend of color between the yellow throats of *L. regale* and George C. Creelman, the somber of *L. sargentiae*, and the greenish of some forms of *L. leucanthum* are marvelous.

However, experience teaches that it is not wise to count too much on the first blossoms. They may and probably will hold their color characters and forms, but their constitutions and propagating qualities are matters for the future to gauge. Our experience with the

West-American martagon hybrids is illustrative. The first selection contained three dozen clons which in 8 years have been reduced to 10. Many of them were discarded because we were not able to propagate them rapidly enough. Propagating quality is very variable. Some do poorly, while others make great festoons when left alone over a few years.

III. *Lilium speciosum*. There is an opportunity for some good work in this group alone as well as in combination with *L. auratum*. Some marvelous hybrids have been produced in the past, but they have been lost.

Work with the group is tedious because the seedlings thus far are slow to multiply. However, to get good seedlings often one need not go outside of the species itself.

The writer made some cross pollinations of *Lilium speciosum magnificum* and *L. speciosum melpomene* about 10 years ago. Some of these seedlings are vast improvements over any of the varieties of this lily known. One of them is especially noteworthy and has been pronounced by good judges the best lily on the Bellingham Bulb Station. But after 5 years of letting alone, undisturbed after the segregation from its progeny at 4 years of age, we have but four bulbs. It is being employed in further breeding.

This gives but a bird's-eye view of the possibilities and the up-to-date accomplishments in the hybridization of the lily. It is not an easy matter at all to get together material for the breeding in the entire genus. Besides a greenhouse is necessary for some of the late-blossoming varieties if one wishes to cover the entire genus. But a great deal can be accomplished with the early and midseason varieties which do not need a greenhouse.

This leaves much untold, for the breeders have not yet given out reports on their results. Your attention is again called in closing to the very large accomplishment of the past 10 or 12 years due in the largest measure to the renewed interest in the lily and the better comprehension of the methods of its propagation. Anyone starting in on lily breeding with limited facilities would do well to decide on some promising line of breeding and follow it up through not less than three generations with as large progenies as possible.

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Sweet Cherry Pollination in Washington for 1931¹

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THERE is still a problem in the pollination of sweet cherries in Washington, and perhaps in other states growing sweet cherries, notwithstanding the fact that pollenizers have been placed in most of the orchards within recent years. In central Washington in the spring of 1931 a normal set from open pollination of as low as 3 to 5 per cent was found on some trees without pollenizers close by, whereas trees adjacent to seedling or pollenizer trees, had a set of as high as 68 per cent. This failure to set fruit was the result of unfavorable weather conditions for pollination which hampered bee activity coupled in many cases with an inadequate number of pollenizer trees or the use of pollenizers which are of only mediocre value.

Several good pollenizer varieties, which were also of fair to good market quality, have been known for a number of years. The market value of these pollenizer varieties, however, has been steadily decreasing within the last few years, until at the present time it is low. It is true that pollenizer trees are worth while in an orchard even though they bring no returns for their own crop. Nevertheless, it is a distinct advantage if the pollenizer trees can produce fruit which approaches the quality and value of the Bing, Lambert, and Napoleon varieties. Until within the last few years, no variety was known that would meet these qualifications. Recent tests, however, have shown the Deacon to be promising. This variety has previously shown promise in trials in Wenatchee, Washington (3) and at Summerland, B. C. (1). As described by Overholser and Overley (4), the Deacon matures in mid-season, slightly earlier than the Bing. It is almost as large as the Bing and with a similar shape. The color of the fruit is very dark red to black, and the juice is red in color while that of the Bing is dark purple in color. The fruit is of slightly softer and less coarse texture than the Bing. The stylar scar of Deacon is about one-half as large as is that of the Bing. The Deacon is of good shipping quality and would pass for the Bing unless a close examination were made.

METHOD OF PROCEDURE

Established methods for hand pollination were used in making the crosses for pollination trials in 1931. Vigorous flowers in the proper stage were emasculated and were pollinated within a period of 48 hours or less after emasculation. Flowers that were not used were

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removed. Pollen used from the different varieties showed a germination varying from 20 to 80 per cent. Two counts were made following pollination, the first about 3 weeks after pollination and the second shortly before harvest. The latter count proved to be more accurate and is used in these data. Cross pollinations were made in the Norton orchard at Grandview, the Brown orchard at Selah, and the Balch orchard at Wenatchee.

TABLE I—POLLINATION RESPONSE OF BING, NAPOLEON, AND LAMBERT CHERRIES

Pollen Parent	Bing		Napoleon		Lambert	
	Set (Per cent)	Normal Set (Per cent)	Set (Per cent)	Normal Set (Per cent)	Set (Per cent)	Normal Set (Per cent)
Bing.....	0	3.0	0	5.2	0	3.3
Napoleon.....	0	3.0	0.36	5.2	0.63	3.3
Lambert.....	0	3.0	0	5.2	0	3.3
Black Republican..	35.4	3.0	14.9	5.2	22.6	3.3
Black Tartarian...	33.6	3.0	19.2	5.2	63.1	3.3
Norma.....	19.8	68.0	20.8	5.2	—	—
Centennial.....	13.9	3.0	—	—	5.0	3.3
Brackett Seedling..	—	—	—	—	20.0	3.3
King Albert.....	0.9	22.2	1.1	30.6	1.3	25.2
Deacon.....	35.6	22.2	48.6	30.6	29.3	25.2
May Duke.....	—	—	9.5	5.2	14.5	3.3
Montmorency.....	23.8	22.2	45.8	30.6	31.0	25.2
Early Richmond...	6.6	22.2	5.4	30.6	4.4	25.2
Parkhill Seedling ¹ ..	7.3	5.4	17.6	24.1	14.5	11.0
Deacon ¹	9.7	5.4	11.6	24.1	38.2	11.0

¹Tests at Wenatchee. Others in Yakima Valley.

Most of the varieties used as pollenizers were sweet cherries (*Prunus avium*). These include Bing, Lambert, Napoleon, Black Republican, Black Tartarian, Centennial, Norma, King Albert, Deacon, and seedlings. Two varieties of sour cherries (*Prunus cerasus*), Montmorency and Early Richmond, were used to determine the cross-compatibility of the two species. May Duke, a hybrid between a sour and a sweet cherry, was also used as a pollenizer. All sets obtained were compared with normal set resulting from open pollination.

The data in Table I show the pollination response of Bing, Napoleon, and Lambert to pollen from the various pollenizers tested.

The Bing. As previously found, the Bing was self-sterile, and inter-sterile with Napoleon and Lambert (2, 3). King Albert also was incompatible with Bing. This variety is a bud sport that has given some promise as an oddity for canning. The pollenizers giving the best set of fruit were Deacon, Black Tartarian, Black Republican, Norma, and Montmorency. These results corroborate previous work done in this state and other states with the exception of Montmorency which had not been previously employed as a pollenizer for the Bing.

The Napoleon. Napoleon was pollinated with pollen from 12 cherry varieties. Similarly to the Bing, the Napoleon proved self-sterile and inter-sterile with the Bing and the Lambert. The King Albert also proved inter-sterile with Napoleon. The best sets were obtained from Deacon, Montmorency, Norma, Black Tartarian, Black Republican, and Parkhill Seedling. May Duke was fairly satisfactory as a pollinizer notwithstanding the fact that it is an interspecific hybrid. Montmorency again indicated its strong compatibility with sweet cherries by the high percentage of fruit set.

The Lambert. Thirteen varieties of pollen were used for crosses with the Lambert. As had been anticipated, the Lambert was self-sterile and inter-sterile with Bing and Napoleon. The best pollinizers were Black Tartarian, Deacon, Montmorency, and Black Republican. The May Duke and seedlings were fairly satisfactory, whereas the Centennial, King Albert and Early Richmond, while giving some set, were not satisfactory as pollinizers.

DISCUSSION

The three principal varieties of sweet cherries grown in the Northwest, namely, Bing, Napoleon, and Lambert, behaved similarly in their response to pollinizers. The outstanding pollinizing variety, both from the standpoint of pollination and marketability was the Deacon. Other excellent pollinizer varieties, which, however, have been declining in market value the last few years, are Black Tartarian, Black Republican, and Norma. Seedling trees are usually good pollinizers but are of no commercial value.

The high percentage set obtained when Montmorency was used as a pollinizer is interesting from the botanical standpoint since inter-specific crosses usually do not result in a high per cent of compatibility. In contrast Early Richmond, although causing some set of fruit, was not nearly as compatible with the sweet cherries as was Montmorency. In the Pacific Northwest the sour varieties are of no value in pollinizing sweet varieties because their normal blooming period is from 5 to 10 days later than that of Bing, Napoleon, and Lambert. The set obtained when May Duke was used as a pollinizer is also interesting from the standpoint that interspecific hybrids are often self-sterile and inter-sterile with either parent. Although the per cent of fruit set was not great enough to consider May Duke in the class of good pollinizers, it indicates that some pollination value is probably realized when May Duke trees are present in a sweet cherry orchard.

Because of the value of Deacon as a pollinizer, it should be known whether Deacon is self-fertile or inter-fertile with Bing, Lambert, and Napoleon. Deacon is self-sterile and will not pollinate itself. Overholser and Overley (3), with one year's results reported that Bing, Lambert, and Napoleon were all satisfactory pollinizers for the Deacon. Britton (1) also reported that the Deacon was satisfactorily

pollinated by Bing, Lambert, and Napoleon in Summerland, B. C. The 1931 pollination tests with these three varieties on Deacon were not satisfactory. It is possible, however, that unfavorable weather conditions were responsible for the poor sets obtained. Further study is probably desirable in establishing the compatibility between Deacon and Bing, Lambert, and Napoleon.

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Pollination Studies With Some Newer Apple Varieties

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IT has seemed almost axiomatic that old varieties give way slowly to new ones, particularly with fruits like the apple that take some time to come into bearing. It has not been so true, however, in recent years. The Delicious is not described in "The Apples of New York," yet today it is the third most important commercial variety in West Virginia. The Golden Delicious, introduced 15 years ago, is known, but perhaps not planted, wherever apples are grown in America. Better methods of transportation and communication and high pressure advertising and salesmanship are mostly responsible. Now come the "color sports." Growers are planting them heavily and are clamoring for information as to their pollination requirements. For the most part this report deals with results secured with varieties that are now being talked about in West Virginia.

Methods of experimentation have been as in previous reports. Wire-screened cages or muslin bags have been used to exclude insects. Stamens and most of the petals were removed in emasculation and not more than 3 flowers per cluster pollinated. Noticeably weak spurs were discarded. Fruit was counted after the first drop.

The Lowry is a Virginia variety that has come into some prominence in recent years in the Shenandoah-Cumberland Valley. Little is known as to its pollination requirements or its value as a pollenizer for other varieties. Time of blooming is in midseason. Pollen was kindly furnished by Mr. W. S. Campfield of Staunton, Va.

TABLE I—SET OF FRUIT ON NORTHWESTERN AT THE EXPERIMENT STATION ORCHARD

1930

Pollenizer	Number of Blossoms Crossed	Number Blossoms Set	Per cent Blossoms Set
Delicious.....	116	38	32.7
Jonathan.....	118	39	33.0

1931

Northwestern.....	342	5	1.5
Starking.....	406	101	24.9
Red Rome.....	528	70	13.3
York.....	404	70	17.3
Lowry.....	441	81	18.4

Results (Table I) indicate that Northwestern is self-sterile and that Starking, Red Rome, Lowry, York, Jonathan, and Delicious

are good pollenizers. Rome seems to be practically self-sterile (Table II). King David, Northwestern, Golden Delicious, Jonathan, Starking, and Lowry pollen gave good sets. Red Rome pollen gave a poor set, as one would expect. Pollen was supposedly ob-

TABLE II—SET OF FRUIT ON ROME AT THE EXPERIMENT STATION ORCHARD

Pollenizer	Number Blossoms Crossed	Number Blossoms Set	Per cent Blossoms Set
1930			
Rome.....	521	3	.6
Red Rome.....	528	28	5.3
King David.....	494	309	62.5
Northwestern.....	531	412	77.6
Golden Delicious.....	649	454	69.9
Jonathan.....	88	65	74.0
1931			
Rome.....	293	11	3.7
Red Rome.....	339	11	3.2
Lowry.....	399	239	59.9
Starking.....	239	174	72.8

tained from the same trees that gave a high set on Rome in 1929 (1). In view of these results it is probable that pollen was gathered by the grower from the wrong trees. Lowry is a good pollenizer for Delicious (Table III).

The variety York is the most important variety in the state, constituting over 15 per cent of the commercial orchards. Field observations indicate that it is sufficiently self-fertile for a commercial crop. Controlled pollination tests have not generally indicated this. Results in 1931 are shown in Table III.

TABLE III—SET OF FRUIT FROM CERTAIN CROSSES AT THE EXPERIMENT STATION ORCHARD

Variety Cross	Number Blossoms Crossed	Number Blossoms Set	Per cent Blossoms Set
1931			
York x York.....	293	1	.03
York x Red Rome.....	201	73	36.3
York x Northwestern.....	241	76	31.5
Delicious x Starking.....	235	13	5.5
Delicious x Lowry.....	254	114	44.9

The York tree used in these crosses was about 15 years old, vigorous and with 50 to 75 per cent of its spurs blooming. Pistils at time of pollinating were in unusually good condition. It is difficult to understand its failure to set when self-pollinated in view of its behavior in solid orchard blocks under field conditions.

There is some indication that pollen from the red sports give a somewhat higher set on the varieties from which they have originated than these varieties selfed. Starking gave a somewhat larger set on Delicious than is usually gotten when Delicious is selfed. Red Rome pollen on Rome gave a higher set than Rome selfed in 1930 but not in 1931.

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Pollination of Certain Apple Bud Sports in North Central Washington^{1,2}

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IN North Central Washington there are at present appreciable plantings of several red colored bud mutations of standard named commercial apple varieties. The growers are interested in knowing the pollination status of these red strains with respect to whether they are self-fertile, inter-fertile with other commercial sorts, and if not what may be satisfactory pollenizers for them. It is of interest also to know the effectiveness of the mutations as pollenizers for the Delicious and Winesap, the two leading standard varieties grown in Washington that tend to be self-fertile.

The mutations whose pollination responses were studied included the Starking, the Richared, and the Shotwell Delicious, all of which are bud sports from the Delicious; the Red Rome; the Blackjon and the King John, from Jonathan; and the Red Winesap, the Red Stayman, and others, whose names indicate the variety giving rise to the mutation.

The work here reported was conducted in northcentral Washington during the seasons 1928 to 1931 inclusive. Standard methods were employed. Not more than three blossoms to a cluster on vigorous spurs were emasculated, the remaining blossoms being pinched off. After emasculation, the flowers were left exposed. Pollen showing 20 to 60 per cent germination was applied within 24 hours after emasculation. The final count was made after the "June drop."

RESULTS WITH DELICIOUS

Work published during the last 10 years by 17 investigators in nine different states definitely demonstrates that the Delicious is self-unfruitful. This is substantiated by the data (Table I) obtained in northcentral Washington. Bud sport varieties and their parents here studied that seem to be satisfactory pollenizers for the Delicious are: Blackjon, King John, Red Rome, Jonathan, and Rome. Those varieties that appear to be cross-unfruitful with Delicious are Red Stayman, Richared, Shotwell Delicious, Starking, and Winesap. The data concerning the value of Golden Delicious as a pollenizer for the Delicious are inconclusive. In 1928 this variety was unsatisfactory, in 1929 highly cross-fruitful, and in 1931 only fairly satisfactory. The Red Winesap appeared doubtful as a pollenizer for the Delicious.

Whitehouse and Auchter (1926) found that the pollen of Golden

¹The data previous to 1930 that are reported were obtained by Mr. William Luce, formerly of the State College of Washington.

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Delicious gave a set of only 5.7 per cent upon the Delicious when the normal set was 16.7 per cent. Knowlton (1929), however, found in West Virginia that the Golden Delicious was a good pollinizer of the Delicious. In 1927 Howlett, using a limited number of flowers, reported the Golden Delicious as an unsatisfactory pollinizer for the Delicious, but in 1929 he recommended the Golden Delicious as satisfactory. These results indicate that the value of the Golden Delicious as a pollinizer for the Delicious is uncertain.

TABLE I—THE POLLINATION RESPONSE OF THE DELICIOUS

Pollen Parent	Years	Total Flowers Pollinated	Total Fruit Set	Average Per cent Fruit Set
Blackjon.....	1931	765	123	16.1
Delicious (selfed).....	1926-31	2,369	34	1.0
Golden Delicious.....	1928	156	5	3.2
Golden Delicious.....	1929	135	32	23.9
Golden Delicious.....	1931	843	67	7.9
Jonathan.....	1926-31	1,304	184	14.1
King John.....	1931	302	47	15.6
Red Rome.....	1929-31	852	100-	11.7
Red Stayman.....	1928	56	0	00.0
Red Winesap.....	1928-31	154	8	5.2
Richared.....	1927, '29, '30, '31	840	17	2.0
Rome.....	1926, '31	1,484	257	17.3
Shotwell Delicious.....	1931	705	5	0.7
Starking.....	1930, '31	789	6	0.1
Winesap.....	1927, '30	359	3	0.8
Normal Count.....	1926, '31	1,841	202	11.0

Vincent (1920) in Idaho; Whitehouse and Auchter (1925) in Maryland; Lantz (1926); Morris and Luce (1926) in Washington; Howlett (1929) in Ohio; and Murneek, Yocum, and McCubbin (1930) in Missouri, obtained good sets from Delicious when pollinated with Jonathan. It is perhaps to be expected that the bud sports of this variety, such as Blackjon and King John would also satisfactorily pollinate the Delicious.

The data obtained in Washington for 2 years indicate that the Red Rome strain employed was a satisfactory pollinizer for the Delicious. This substantiates the findings of Morris and Luce (1928), and is to be expected since the Rome has been found by most investigators to be a good pollinizer for the Delicious. Howlett (1929), however, did not obtain a set upon Delicious with pollen of Gallia, (probably a seedling of Red Rome). Young trees of Red Rome tend, however, to bloom somewhat later than the Delicious.

In the limited number of trials in Washington, the Red Stayman was entirely inadequate as a pollinizer for the Delicious. It would not be expected that Red Stayman strains would be satisfactory, since the Stayman itself has been found so unsatisfactory.

Likewise, the Red Winesap did not pollinate the Delicious. This also would be expected from the fact that the true Winesap is unsatisfactory as a Delicious pollinizer.

Since the Delicious is self-sterile, it is not inconsistent to find that the Richared, a mutation of the Delicious, is inter-sterile with the latter, as shown by 4 years' data. Morris and Luce (1928) also reported this to be the case.

RESULTS WITH WINESAP

The evidence obtained by investigators is that the Winesap is self-unfruitful. Those varieties and strains which the data in Table II indicate are satisfactory pollenizers for the Winesap are: Delicious, Richared, Starking, Golden Delicious, King John, and Red Rome. Red Stayman and Stayman appear cross-unfruitful upon Winesap.

TABLE II—THE POLLINATION RESPONSE OF THE WINESAP

Pollen Parent	Years	Total Flowers Pollinated	Total Fruit Set	Average Per cent Fruit Set
Blackjon	1931	315	32	10.0
Delicious	1926-31	6,541	1,733	26.5
Golden Delicious	1928-31	545	108	19.8
Jonathan	1928-30	429	79	20.0
King John	1931	69	12	17.4
Red Rome	1928-30, '31	537	74	12.9
Red Stayman	1928	100	0	0.0
Richared	1928-30, '31	564	52	9.2
Rome	1930	322	72	22.3
Starking	1930-31	494	47	9.5
Stayman	1928	100	3	3.0
Winesap (selfed)	1926-30	3,491	34	1.0
Normal Count	1928-30, '31	442	56	9.67

RESULTS WITH RICHARED

The Richared blossoms employed for pollination were on trees about 7 years old and hence the set may have been less than would have been the case on more mature trees.

The Richared (Table III) was self-unfruitful, failed to set satisfactorily with pollen from Delicious, Starking, and Shotwell Delicious. The Richared seems to be adequately cross-fertilized by King David, McIntosh, Ortley, Rome and Winter Banana. The Golden Delicious, King John, and Red Rome, were only partially satisfactory as pollenizers for the Richared. In 1929, the Yellow Newtown gave an excellent set on the Richared, but in 1930 and 1931, the set was unsatisfactory.

The data for 1931 with emasculated Richared flowers exposed but not hand pollinated indicate that chance pollination by insects or winds is negligible. Out of 566 flowers so treated only two set fruit.

RESULTS WITH STARKING

The Starking blossoms pollinated were on grafts 4 years old on trees approximately 15 years old. The data in Table IV show the Starking to be self-unfruitful, and to be inter-unfruitful with Delicious and Shotwell Delicious. Varieties indicated as satisfactory pol-

lenizers for the Starking are Blackjon, Golden Delicious, and White Winter Pearmain.

TABLE III—THE POLLINATION RESPONSE OF THE RICHARED

Pollen Parent	Years	Total Flowers Pollinated	Total Fruit Set	Average Per cent Fruit Set
Delicious.....	1930-31	422	3	0.7
Golden Delicious.....	1929-31	324	18	5.6
King David.....	1927	72	12	17.0
King John.....	1931	201	9	4.5
McIntosh.....	1929-31	287	52	18.1
Ortley.....	1929	72	9	12.5
Richared (selfed).....	1927-29, '30, '31	543	9	1.7
Red Rome.....	1930-31	401	14	3.5
Rome.....	1929-31	283	59	20.8
Starking.....	1930-31	371	4	—
Shotwell Delicious.....	1931	153	1	0.7
Winter Banana.....	1928	67	30	45.0
Yellow Newtown.....	1929	25	16	64.0
Yellow Newtown.....	1930-31	394	8	2.0
Normal Count.....	1930-31	1,489	99	6.6
Emasculated only, no pollen applied.....	1931	566	2	0.35

TABLE IV—THE POLLINATION RESPONSE OF THE STARKING

Pollen Parent	Years	Total Flowers Pollinated	Total Fruit Set	Average Per cent Fruit Set
Blackjon.....	1931	203	25	12.32
Delicious.....	1930-31	348	0	0.0
Golden Delicious.....	1931	214	32	14.95
Shotwell Delicious.....	1931	73	0	0.0
Starking.....	1930-31	366	0	0.0
White Winter Pearmain...	1931	144	29	20.14
Normal Count Average...	—	1,385	348	18.83

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Pollination of the McIntosh Apple in the Champlain Valley—Third Progress Report

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THIS paper summarizes the third year's results in a series of studies initiated in 1929 and 1930 and previously reported (1, 2). The matters under investigation are, (1) the value of different pollen varieties in causing McIntosh to set fruit, (2) the effect on set of fruit of pollinating the same unit branches for several years in a solid McIntosh block, and (3) the distance over which pollen bouquets are effective in increasing the set of fruit.

In 1931, weather during the blooming period of the orchards in question was unfavorable for pollination, being cool and rainy. The 24-hour temperature ranges of the 13 days during which McIntosh was in bloom were respectively, 53 to 73, 44 to 63, 44 to 55, 40 to 51, 40 to 62, 45 to 53, 44 to 66, 43 to 57, 35 to 57, 31 to 70, 53 to 82, 60 to 86, and 57 to 77. On the first two and last two days, relatively few blossoms were at the proper stage to benefit by pollination. There was some rain on the first six, the eighth, twelfth, and thirteenth days. Most days afforded intervals during which the bee flight occurred to a limited extent. In these orchards as a whole, satisfactory McIntosh yields were obtained only in the immediate vicinity of trees of other varieties. These weather conditions are in marked contrast to those of the preceding two years. In 1929, the weather was uniformly warm and sunny, while in 1930, it was between the extremely favorable weather of 1929 and the unfavorable weather of 1931. Orchard No. 2 in Table II bloomed a few days later and had favorable weather for pollination.

For nearly all of the work, the branch-unit method was used. Uniform branches about an inch in diameter were selected, and when most of the blossoms were open, pollen of the desired variety, previously collected and dried, was brushed onto the stigmas of two or three blossoms of each cluster. Where it was desired to compare the effectiveness of different pollens, a cheesecloth bag, 3 by 6 feet, covered the branch from the time when the most advanced blossoms were in full pink stage until after petal fall, to prevent insect visitation. Where it was desired merely to determine whether lack of cross-pollination was limiting the set, the branches were exposed to natural agencies throughout. All batches of pollen were tested and only those showing at least moderately good germination were used.

DIFFERENT VARIETIES AS MCINTOSH POLLENIZERS

Table I summarizes the effect of five standard pollen varieties on yield of McIntosh over a 3-year period. Each unit branch received pollen of the same variety for three successive years. Probably the best single criterion of the behavior of the branches is the column giving the percentage of all spurs with fruit, 1929-1931, inclusive.

TABLE I.—YIELD OF BAGGED MCINTOSH UNIT BRANCHES HAND-POLLINATED WITH THE SAME POLLEN VARIETY 3 SUCCESSIVE YEARS
TREES MODERATELY VIGOROUS

Branch No.	Pollen Variety	Total No. Spurs				No. Spurs Blossoming				No. Spurs Maturing Fruit				Per cent Blooming Spurs with Fruit 1929-1931 Incl.	Per cent All Spurs with Fruit 1929-1931 Incl.
		1929	1930	1931	Sum of 3 Yrs.	1929	1930	1931	Sum of 3 Yrs.	1929	1930	1931	Sum of 3 Yrs.		
9	Fameuse	84	83	117	284	73	39	85	197	39	11	30	80	41	28
11	Fameuse	75	69	94	238	61	9	78	148	35	5	27	67	45	28
13B	Fameuse	91	94	120	305	78	41	88	207	33	14	24	71	34	23
19	Fameuse	87	110	136	233	70	62	93	225	44	9	12	15	24	28
22	Fameuse	60	59	93	212	45	24	80	149	30	18	29	77	52	36
25	Fameuse	57	41	100	198	51	12	77	140	19	3	19	41	29	21
Average.	Fameuse	—	—	—	—	—	—	—	—	—	—	—	—	38	27
8	Tolman	100	75	154	329	86	18	119	223	40	9	43	92	41	28
14	Tolman	91	101	129	321	66	35	104	205	36	10	25	77	35	22
Average.	Tolman	—	—	—	—	—	—	—	—	—	—	—	—	38	25
7	Delicious	51	77	115	243	37	15	90	142	25	7	25	57	40	23
10	Delicious	86	83	149	318	68	24	100	192	28	12	24	64	33	20
13A	Delicious	85	76	109	270	70	31	87	188	34	14	29	77	41	28
20	Delicious	109	74	102	285	99	18	64	181	45	3	11	59	33	21
21	Delicious	76	94	148	318	66	20	109	195	36	9	33	78	40	25
24	Delicious	58	62	87	207	55	19	70	144	23	7	16	46	32	22
Average.	Delicious	—	—	—	—	—	—	—	—	—	—	—	—	37	23
6	Cortland	66	61	96	223	48	9	85	142	19	4	18	41	29	18
16	Cortland	81	40	65	186	69	19	41	129	22	8	12	42	33	23
Average.	Cortland	—	—	—	—	—	—	—	—	—	—	—	—	31	21
5	McIntosh	71	77	124	272	67	50	116	233	7	3	0	10	4	4
12	McIntosh	63	65	88	216	58	36	72	166	9	0	0	9	5	4
15	McIntosh	83	87	118	288	66	69	76	211	3	0	0	3	1	1
Average.	McIntosh	—	—	—	—	—	—	—	—	—	—	—	—	3	3
2	Check ¹	94	84	101	279	87	73	93	253	14	14	7	35	14	13
3	Check ¹	73	64	114	251	66	47	93	203	7	10	9	26	13	10
4	Check ¹	74	39	132	245	64	20	116	200	12	0	16	28	14	11
7	Check ¹	73	83	125	281	56	43	62	167	7	4	0	11	7	4
Average.	Check ¹	—	—	—	—	—	—	—	—	—	—	—	—	12	10

¹Not bagged—natural open pollination.

TABLE II.—YIELD OF MCINTOSH UNIT BRANCHES POLLINATED WITH SOME OF THE NEWER POLLEN VARIETIES, 1931

Orchard and Tree No.	Branch No.	Bagged or Open	Pollen Variety	No. Blossom Spurs	No. Spurs with Fruit June	No. Spurs with Fruit Sept.	Per cent Blossoming Spurs with Fruit Sept.
Orchard 1... Tree 1...	1	Bag	Early McIntosh	60	17	9	15
	2	Bag	Milton	53	7	1	2
	3	Bag	Kendall	65	20	12	18
	4	Bag	Delicious	80	25	21	26
	5	Bag	Lobo	105	43	21	20
	1B	Open	Unknown	44	5	3	17
	2B	Open	Unknown	55	8	8	15
Tree 2...	11	Bag	Early McIntosh	72	11	3	4
	12	Bag	Milton	76	25	6	8
	13	Bag	Kendall	106	18	13	12
	14	Bag	Delicious	107	36	5	5
	15	Bag	Lobo	77	28	18	23
	1C	Open	Unknown	49	6	0	0
	2C	Open	Unknown	91	8	3	3
Tree 3...	16	Bag	Early McIntosh	149	78	11	7
	17	Bag	Milton	107	43	14	13
	18	Bag	Kendall	71	18	11	15
	19	Bag	Delicious	125	34	21	17
	20	Bag	Macoun	163	23	11	7
	1D	Open	Unknown	97	10	5	5
	2D	Open	Unknown	40	5	1	3
Tree 4...	21	Bag	Early McIntosh	99	65	25	25
	22	Bag	Milton	150	55	33	22
	23	Bag	Kendall	91	37	26	29
	24	Bag	Delicious	100	59	45	45
	25	Bag	Macoun	105	31	27	26
	1F	Open	Unknown	55	1	1	2
	2F	Open	Unknown	95	38	20	21
Orchard 2... Tree 1...	1	Bag	Macoun	41	30	11	27
	2	Bag	Lobo	41	35	10	24
	3	Bag	Medina	57	46	27	47
	4	Bag	Delicious	60	38	23	38
	1A	Open	Unknown	59	50	19	32
	2A	Open	Unknown	108	43	18	17
Tree 2...	5	Bag	Macoun	96	55	10	10
	6	Bag	Lobo	47	33	9	19
	7	Bag	Medina	52	35	4	8
	8	Bag	Delicious	65	39	17	26
	1B	Open	Unknown	42	25	14	33
	2B	Open	Unknown	55	25	7	13

Fameuse, Tolman, Delicious, and Cortland pollens have all produced satisfactory yields, averaging more than double that of naturally pollinated check branches and seven to nine times that of self-pollinated branches. It is doubtful if the differences among these four

varieties are significant, as judged by the 3-year record. It is probable that such differences as existed the first year (1) have been largely offset by increased tendency toward alternation on the part of branches receiving the most potent pollens.

Further evidence of the relative value of pollen of these standard varieties was sought through seed counts. The average number of seeds per McIntosh fruit in 1931 according to pollen parent was as follows: Tolman (22 fruits), 8; Delicious (49 fruits), 7.5; Fameuse (54 fruits), 6.0; Cortland (19 fruits), 5.3. This order of the pollen varieties is the same as results from arranging them according to yield of unit branches in the studies of 1929 and 1930 (1, 2).

Table II shows the yield of McIntosh unit branches pollinated with some of the newer pollen varieties in 1931. Some low temperature injury to the buds and opening blossoms in the orchards where this work was carried on probably accounts in large measure for the irregularity in results. Since Delicious pollen was known to be among the best, it was used as the criterion. The variation in yield is about as great in branches pollinated with Delicious as in those pollinated with the other varieties. The average number of seeds per McIntosh fruit pollinated by Medina (20 fruits) was, 8.7; by Lobo (17 fruits), 6.4; by Macoun (18 fruits), 5.2; by Delicious (23 fruits), 8.3. The data suggest that Early McIntosh, Milton, Kendall, Lobo, Macoun, and Medina all offer some promise as McIntosh pollenizers. Further studies of the effectiveness of these pollens, and of the blossoming dates of the varieties are needed.

OPEN POLLINATION IN A SOLID MCINTOSH BLOCK

The data about to be presented carry forward for one year, the results previously published (1, 2). Table III shows the yield of 13 McIntosh unit branches hand-pollinated three successive seasons and of 13 adjacent naturally pollinated branches. Both pollinated and check branches were exposed to natural agencies through the blossoming period. The work was done in a 16-acre solid McIntosh block which is a part of a 90-acre orchard in which 95 per cent of the trees are McIntosh. Each year, bees were scattered through the orchard in groups of four to eight colonies at a location, at the rate of one per acre. In 1929, there was about one pollen bouquet per acre; in 1930, two per acre, and in 1931, three per acre. Each bouquet consisted of as many blossoming branches averaging 1 inch in diameter at the butt as could be forced into a lime-sulfur drum out of which the head had been chopped. Each drum containing a bouquet rested on an empty lime-sulfur drum on the southwest side of a tree and directly against it. In 1929 and 1930 the bouquets consisted of branches of different varieties, mostly wild. In 1931, Fameuse branches were used almost entirely. Weather was extremely favorable for flight of bees in 1929, only moderately so in 1930, and distinctly unfavorable in 1931.

Table III shows that the 3-year yield of the hand pollinated branches is about double that of the naturally pollinated branches. The 3-year yield of the hand pollinated branch is greater than that of the corresponding check branch in all 13 cases. As would be expected, the check branches showed less tendency toward alternation in blossoming and fruiting than did the hand pollinated branches. The check branches developed a larger number of blossoms during the 3-year period. How closely the actual number of blossoming spurs approached the maximum possible number was judged by dividing the total number of blossoming spurs during the 3-year period by the total number of spurs. It was found that on the pollinated branches there were 58 per cent of the maximum possible number of blossoming spurs, and on the check branches, 65 per cent.

In 1931, seed counts on lots of six or more fruits were made for five hand-pollinated branches and for the five corresponding check branches. The average numbers of seeds per apple in the five pairs, with the hand-pollinated branch stated first were, respectively, 5.6 and 3.4, 5.8 and 4.1, 6.6 and 3.7, 6.5 and 3.9, 5.0 and 3.0. These seed counts are roughly parallel to the data on yield of the hand-pollinated and check branches.

EFFECT OF POLLEN BOUQUETS

Table IV shows the strikingly local effect of pollen bouquets in the cool, rainy blossom period of 1931 in the 16-acre solid McIntosh block. For each of six bouquets, a criterion branch (No. 1) was chosen adjacent to the bouquet, another (No. 2) on the opposite side of the same tree, and a third (No. 3) on the near side of an adjacent tree, still further from the bouquet. In all six cases, branch No. 1 has much the heaviest set in June. The average per cent of blossoming spurs with fruit in June for branch No. 1 is 57; for branch No. 2, 9; and for branch No. 3, 18. The relatively heavier set for branch No. 1 persisted to harvest in four of the six cases. The average per cent blossoming spurs with fruit in September is 23 for branch No. 1, 4 for branch No. 2, and 7 for branch No. 3. As a further means of studying the effect of pollen bouquets, the number of seeds per apple on branch No. 1 and branch No. 3 was determined for each of six bouquets. With a single exception, they were not the bouquets listed in Table IV. Each figure is an average of counts on 10 fruits. The average numbers of seeds per fruit for branch No. 1 and the corresponding branch No. 3 are, respectively: 10.5 and 4.0, 8.7 and 3.8, 10.1 and 3.6, 9.1 and 3.8, 10.5 and 2.4, 8.6 and 2.6, 8.6 and 2.6. The yield of this block of trees was light except on the side of a tree adjacent to a bouquet.

This situation in a year of cool, rainy blooming weather is in marked contrast to the situation in 1930 when weather during bloom was more favorable. In that year the yield throughout the block where two bouquets per acre were used, was fairly good, the yield of branch No. 1 being about the same as that of branch No. 2 and branch No. 3.

TABLE IV.—SET OF FRUIT AS AFFECTED BY DISTANCE FROM POLLEN BOUQUETS IN A 16-ACRE SOLID MCINTOSH BLOCK DURING A COOL, RAINY BLOSSOM PERIOD, 1931

Bouquet No.	Branch No.	Total No. Spurs	No. Blossom Spurs	No. Spurs with Fruit June	No. Fruits June	Per cent Blossom Spurs with Fruit June	No. Spurs with Fruit Sept.	Per cent Blossom Spurs with Fruit Sept.
I	1 ¹	144	126	90	123	71	48	38
	2	114	86	5	5	6	3	4
	3	96	49	2	2	4	3	6
II	1	144	109	68	87	62	36	33
	2	51	41	2	2	5	2	5
	3	96	85	16	19	19	4	5
III	1	87	69	38	55	55	15	22
	2	211	165	9	9	5	6	4
	3	67	48	6	6	33	2	4
IV	1	131	111	59	63	53	7	6
	2	89	77	14	14	18	0	0
	3	112	87	13	13	15	6	7
V	1	64	60	27	36	45	12	20
	2	109	88	12	17	14	6	7
	3	124	104	10	11	10	7	7
VI	1	64	61	33	40	54	10	16
	2	87	71	6	6	8	4	6
	3	97	66	19	19	29	10	15

¹In each case, branch No. 1 is adjacent to the bouquet, branch No. 2 on the opposite side of same tree and branch No. 3, beyond branch No. 2, on the near side of the next tree.

CONCLUSIONS

Hand pollination of the same McIntosh branch units for three successive years with Fameuse, Tolman, Delicious, and Cortland, respectively, resulted in satisfactory yields in all cases. Results in 1931 suggest that Early McIntosh, Milton, Kendall, Lobo and Macoun offer some promise as McIntosh pollenizers. In a solid McIntosh block, hand pollination of the same unit branches for three successive years resulted in doubling the yield. Data are presented illustrating the strikingly local effects of bouquets during a cool rainy blossoming period. Seed counts supplement all yield records.

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A Device to Facilitate Pollen Distribution by Bees

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THE chief disadvantage of hand pollination in commercial orchard practice is the immense amount of labor involved both in gathering and in applying the pollen. Perhaps in some cases, the bee pollen-coater herein described or some modification of it, will make possible more economical pollen distribution. Its purpose is to send the bees from the hive laden with pollen. The method is to force the bees to walk through a quantity of pollen upon entering and leaving the hive.

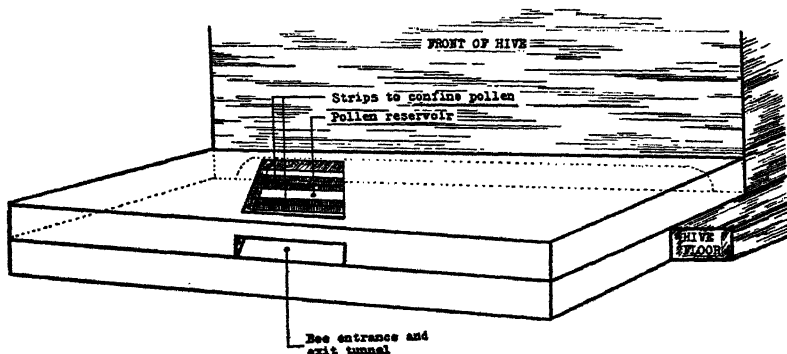


FIG. 1. Bee pollen-coater in working position.
(Glass plate, not shown is laid on top to form roof of tunnel.)

The bee pollen-coater is a modification of what is known to beekeepers as a winter hive entrance block. The latter is essentially a diagonal horizontal tunnel about 6 inches long, 3 inches wide and $\frac{1}{2}$ inch high, attached to the front of the hive. Its ordinary use is to permit free passage of the bees in and out of the hive at will, but at the same time, to check air currents that would chill the colony.

For the present purpose, the roof of the tunnel is removed. Two wooden strips each $\frac{1}{4}$ -inch high are nailed across the floor of the tunnel, thus forming an enclosure to contain the pollen. A glass plate is substituted for the original roof of the tunnel so that one may observe the bees and determine readily when the pollen supply needs replenishment. A piece of wood is laid on the glass plate in sunny weather to prevent excessive heating of the pollen. The bee pollen-coater in working position is shown in Fig. 1.

About 15 of these bee pollen-coaters were in operation in the plantings of Chazy Orchards, Inc., during the blooming period of 1931. The only measure of their effectiveness, however, was the preliminary experiment about to be described.

Two comparable McIntosh trees just attaining good vigor after years of neglect and each having a spread of about 12 feet were caged with cheesecloth. Such blossoms as were open (about 50 per cent) were removed. Into one cage was introduced a hive of bees with no outside pollen supply. Into the other was introduced a hive of bees equipped with a loaded bee pollen-coater. The pollen was obtained from wild apple trees, the anthers being collected at the "balloon" stage of the blossoms and dried in a warm room on open plates. Germination tests showed the viability of this pollen to be of a low order. The dried anthers, covered with pollen, were placed in the pollen reservoir and the supply replenished when necessary on two subsequent days.

On the afternoon when this test was started, the weather was warm and sunny. The bees caged with the check tree were active in the blossoms. However, the colony chosen to test the new device proved so weak that few bees ventured from the hive. A more vigorous colony was substituted the next day, but the weather for the remainder of the season was so cool and windy, that flight of bees was very scanty.

The activity of the bees was observed. A majority of them walked over or through the anthers in the pollen reservoir paying little attention to them except as obstacles in their path. Some, however, carried anthers out of the reservoir depositing them on the ground. Others carried them into the hive. The reservoir contained about 20 cubic centimeters of dried anthers in a loose condition. It required refilling about every 20 minutes during active bee flight of a populous colony.

Even with adequate distribution of good pollen the ability of the trees in this block to set was of a low order, as indicated by hand pollination of branch units with viable pollen of good varieties such as Delicious. Notwithstanding these unfavorable factors, the results suggest that the method may have possibilities. The yield of the treated tree was 42 pounds of fruit against 7 pounds for the check tree. A majority of the fruits from the treated tree had 3 or more seeds, while a majority of those from the check tree had only 1.

Before such a device could merit acceptance as a practical appliance for use in commercial orchards, proof would be necessary that it was effective in bringing about pollen distribution, and that it was economical in use of pollen. Obviously, it would be useful only when weather conditions are conducive to flight of bees. However, pollen could be collected in the usual way, and either applied by hand or supplied to bees by means of the bee pollen-coater, according to the weather.

Further Observations on Factors Affecting Fruit Setting of the McIntosh Apple in New Hampshire

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IN 1931 pollination experiments were carried on essentially the same as reported in a previous paper (1). In that paper results are presented dealing with the efficiency of several standard commercial varieties as pollenizers of McIntosh for three seasons with consistency in the values obtained. At present one of the leading questions of growers in New Hampshire is the efficiency of newer varieties as pollenizers, because of the desire to try out some of the new McIntosh-like sorts. It was therefore considered that some value to growers might be derived from using some of the newly originated varieties as pollenizers for McIntosh. With this point of view in mind the writer ceased testing as pollenizers varieties which had shown themselves to be consistently good pollenizers, and also varieties which had proven less desirable from a standpoint of commercial value.

In order to increase the amount of data to be obtained and to compare effects in differently located sections, a McIntosh tree was caged in cheese cloth in a southern New Hampshire orchard where normally trees of a given variety come into bloom from 4 to 7 days earlier than at Durham. At Durham two McIntosh trees, 12 years old, were enclosed in cheese cloth cages. Two young Cortland trees were also caged and reciprocal crosses made. McIntosh pollens were also used.

Weather conditions were unusually favorable for fruit setting in 1931. Bright sunshine and high temperature prevailed with little rain during the period of full bloom. The least favorable feature was the rapidity with which the trees came into full bloom and the shortness of the period when stigmas were receptive.

Pollen was applied this season only to lateral flowers in the cluster, all terminals being removed. Another feature which differed from previous experiments and which it was thought would give more uniform results was the pollination of four flowers in every cluster used. This procedure was adopted on the basis of results presented previously (1) which show that three or more flowers are generally necessary per spur to obtain a maximum set of fruit. Although the data referred to (1) shows that the same is true when three flowers are pollinated, four receptive flowers were used as a factor of safety.

Counts of set were made after the June drop. The June drop was light during 1931. This may have been due to the fact that there was an unusually large amount of rainy weather during the early growing period.

A second or late drop, unusual in New Hampshire, occurred in August (about a month after the June drop). The amount of fruit

TABLE I—SET OF FRUIT OBTAINED IN HAND-POLLINATION TESTS ON CAGED MCINTOSH TREES IN NEW HAMPSHIRE WITH VARIOUS VARIETIES AS POLLENIZERS, 1931

Pollen Variety	Number of Flower Clusters Pollinated at			Number of Flowers Pollinated at			Per cent of Spurs Setting Fruit at			Per cent of Flowers Setting Fruit at		
	Durham			Durham			Durham			Durham		
	A	B	Atkinson C	A	B	Atkinson C	A	B	Atkinson C	A	B	Atkinson C
Medina.....	77	111	175	308	444	700	81.8	75.7	50.3	38.0	25.1	13.9
Delicious.....	64	107	—	256	428	—	78.1	74.8	—	27.0	32.5	—
Orleans.....	—	—	102	—	—	408	—	—	44.1	—	—	12.3
Cortland.....	71	143	—	284	572	—	87.3	57.3	—	34.9	17.2	—
Fameuse.....	63	6	29	252	54	116	77.8	66.7	37.9	37.3	30.6	10.3
Milton.....	67	—	99	268	—	396	83.6	—	27.3	31.0	—	6.8
Lobo.....	42	55	99	168	220	396	78.6	60.0	29.3	32.8	24.6	7.8
Wagener.....	69	187	70	276	748	280	69.6	65.3	30.0	37.2	29.0	8.9
Melba.....	91	32	154	364	128	616	78.0	53.1	29.3	33.0	17.2	8.9
Gravenstein.....	46	98	35	184	392	140	13.0	3.1	2.9	3.8	0.8	0.7
Red Gravenstein.....	53	11	84	212	44	336	3.8	9.0	2.4	0.5	2.3	0.6
McIntosh.....	39	104	53	156	416	212	0	4.8	0	0	1.2	0
Check.....	106	528	364	424	2,112	1,456	0.9	0.2	0	0.2	.05	0
Total.....	788	1,382	1,264	3,152	5,528	5,056	—	—	—	—	—	—
Hand pollinations.....	682	754	900	2,728	3,016	3,600	—	—	—	—	—	—

dropping at that time seemed to depend a good deal on the individual tree, some trees showing a rather heavy drop. Trees that were hand pollinated dropped much less fruit than trees left to the work of bees and other insects. The drop on hand pollinated trees was less than a dozen fruits on the average. This was from 1 to 5 per cent as much as the drop recorded on other trees. This may have been partly due to the slightly greater total crop on open pollinated trees. A more probable explanation, however, is the fact that hand pollinated flowers were more thoroughly pollinated and with better or more effective pollen than might have been the case with open orchard trees. It was a notable fact that on some branches of the McIntosh trees fruit set so thickly that apples touched one another all along the branch, yet good size was obtained and no drop occurred. An amazingly small ratio between number of leaves and fruits must have occurred on such branches. This may have been compensated for by check branches which were nearly devoid of fruit.

Table I represents the set of fruit obtained on the three different McIntosh trees, with the total number of flowers and spurs pollinated. The consistency of the results obtained should be noted. Tree A, as judged by the type of growth was the most vigorous used in the experiment. The weakest was tree C located at Atkinson. The location of this tree in a hollow with poor air drainage and in an early blooming section was not in its favor. The blossom buds had apparently suffered very slightly from frost. This was judged from the weak manner in which the flower buds opened and from the fact that individual flowers often remained stuck together even after attaining their full size. This slight injury probably accounts in part for the poorer set on this tree.

In spite of the effect of climatic factors and variations in orchard soil management, the results with different pollenizers appear to be consistent. As usual the variety Delicious was outstanding in causing a high set of fruit on McIntosh. Gravenstein was again shown to be a very poor pollenizer for McIntosh. Red Gravenstein behaves similarly, the average set for the three McIntosh trees being 6.3 per cent of all the blossom spurs when Gravenstein pollen was used, and 5.1 per cent when Red Gravenstein was used as pollenizer. The percentage of blossom spurs setting fruit when the McIntosh was hand self-pollinated was only 4.8 per cent on tree B. No fruit set with self-pollination on the other two trees. Check spurs showed a slight set on trees A and B, but no set on tree C. It is doubtful if even self-pollination had a great effect on the development of the one fruit that set on check spurs since this fruit was rather large, somewhat irregular in shape, and possessed a large open core in which not a vestige of shrivelled seeds or ovules could be detected although one plump seed had developed in the fruit. This phenomenon occurred in some of the check fruits in previous years. This was different from the case of fruits setting after the application of Gravenstein pollen. In such cases the development of the fruit was

considerably diminished and shrivelled seed and ovules could be detected. Also core development was diminished. It seems possible that parthenocarpy has played a part in the development of the check fruits.

It is interesting to note that with less vigorous trees, there is a greater difference in relative effectiveness between the better pollenizers. On the most vigorous tree (A) there is little or no difference between the set of fruit when the several different good pollenizers are used. The differences become rather apparent on the weakest tree (C). Such data as this and previous results (1) strengthen the opinion that more importance should be attached to the choice of varieties to be used as pollenizers, especially when the vigor of the trees in an orchard is below average. In this respect one should be careful not to draw upon such varieties as Gravenstein and Red Gravenstein, which are outstandingly poor pollenizers even for flowers on vigorous McIntosh trees. In choosing pollenizers, too, one must still be influenced by other factors than set of fruit as determined by hand pollination. Since these other factors are so well known to workers in the field of pomology there is no need to discuss that phase here.

Provided other conditions are favorable, data from Table I indicates that with the less vigorous McIntosh tree, Delicious and apples of the Delicious type head the list of efficient pollenizers. Thus, in the case of trees B and C, Medina and Orleans, which originated as a cross between Deacon Jones and Delicious, and Delicious itself, head the list. The good qualities of Delicious pollen seem to be carried on to its descendants.

Table I also presents a comparison of Famuese and of some descendants of McIntosh with one another as to their suitability as pollenizers for McIntosh. Milton, Cortland, Lobo, Melba, and Famuese rank about the same as pollenizers for the McIntosh, giving a satisfactory set in every case, yet not differing markedly from one another in efficiency. Wagener, during the past season, behaved in a similar fashion to these McIntosh-like varieties.

Other workers in the field of apple pollination have occasionally expressed fear that an orchard might become over-pollinated by the introduction of exceptionally good pollenizers. Aside from the fact that to overcome such a difficulty, the sparse setting of such pollenizers may be practical, a glance at Table I will tell that even very good pollenizers may not be more than just effective where the trees are not in possession of great vigor. Thus the average value of the McIntosh-type varieties of pollenizers is 81 per cent in the case of vigorous tree A and 31 per cent in the case of tree C, yet tree C produced a paying, though moderate, crop. In the orchard where trees A and B were located, 55 per cent of the blossoming spurs of all the McIntosh trees retained fruit after the June drop. Fifty-five per cent of all the spurs in this orchard were blossom spurs. The result was a moderately heavy crop of fruit. In the orchard where tree C

was located, 61 per cent of all the spurs on McIntosh trees produced bloom while 22 per cent of those that bloomed produced fruit. In this orchard the crop was just sufficient to pay for itself. These two orchards were well supplied with pollenizers.

In another orchard of trees of approximately the same age as those in the Atkinson orchard, but which consisted only of McIntosh, Gravenstein, and Baldwin, 32 per cent of the blossoming spurs of the McIntosh trees set fruit while 29 per cent of the total spurs on the trees were blossom spurs. The crop produced under such conditions was about 70 per cent that produced in the Atkinson orchard. In a nearby orchard pollenizers were located and from a comparison with the results in that orchard it is felt that the bees must have flown between the two orchards.

As in previous years (1) there was noted a difference in the ability of different pollens to cause seeds to develop in McIntosh fruit. Delicious headed the list, causing the development of an average of 9.5 seeds per apple on tree A and 8.7 on tree B. Melba, Medina, and Wagener were close competitors with Delicious, producing 9.5, 9.4, and 9.3 seeds per apple respectively in the case of tree A, and 8.6, 8.4, and 8.4 seeds respectively in the case of tree B. Extremely low numbers of seeds were developed in McIntosh apples pollenized by McIntosh, Gravenstein, and Red Gravenstein, namely, 3.6, 2.6, and 2.3 seeds respectively per apple.

From 40 to 75 per cent of the apples in these latter cases were lop-sided, while with the rest of the pollenizers listed in Table I only from 2.6 to 14.6 per cent of the fruit was lop-sided.

Although one seed less was developed on the average in apples on the weaker tree B, the relative efficiency of pollenizers in causing seed development keeps the same order in both tree A and tree B. There was also a slightly lower percentage of lop-sided fruit in most cases of high seed content on tree A than on tree B. If increased number of seeds should insure increased set and improved form and appearance, the better pollenizers should be chosen.

The data presented in Table I indicate that more attention should be directed toward expressing fruit set on the basis of spurs rather than individual flowers. From a practical point of view one can judge the potential crop better when data is presented in the former way. The high set indicated by noting the percentage of flowers setting fruit is misleading where a large percentage of the spurs produce two or more fruits. In this case some of the fruit would be thinned, leaving generally only one fruit to a spur at most. Therefore, the flower-set count would greatly over-estimate the potential commercial crop. For example, the trees C, in the Atkinson orchard produced rarely more than one apple per spur; hence, as Table I shows, the per cent set of spurs in the same orchard was nearly four times that of individual blossoms set. On the other hand, on tree B the percentage of spurs setting fruit was generally $2\frac{1}{2}$ to 3 times the percentage set of blossoms because many spurs set two fruits. On tree A the per-

centage of spurs setting fruit was 2 to $2\frac{1}{2}$ times the percentage of flowers setting fruit because of the excessive number of spurs setting 2 or 3 fruits. Furthermore, the percentage flowers setting fruit on tree C was on the average one-fourth the percentage of flowers setting fruit on tree A. In the case of spurs, one-third to one-half as many spurs set fruit on tree C as on tree A. This spur-set count gives a truer picture of the real commercial crop than the flower-set. Tree A where the better pollenizers are concerned, would need considerable thinning to produce fruit of the desired color and quality. This would bring the total crop of tree A still nearer to that on tree C. In presenting pollination data too much emphasis has probably already been placed on making conclusions from the figures as they stand without considering the orchard operations that still must be carried out to make the fruit of more acceptable market value.

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Apple Breeding: Statistical Analysis of Apple Breeding Material^{1, 2}

By S. W. EDGECOMBE, and H. L. LANTZ, *Iowa State College,
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IN previous reports to this society (1, 5, 7, 8) it has been shown that varieties differ in their ability to transmit vigor to their progeny and that a consideration of vigor is important in fruit breeding.

This investigation³ has been carried out on 40 crossbred apple progenies involving 3,238 seedlings ranging from 8 to 11 years in age. Its object was to determine the ability of the various parent varieties when crossed with other varieties to transmit desirable vigor and grade to their progeny. The grade and vigor measurements were obtained as described previously (6). The detailed calculations and tests of significance have been reported (3). In this paper these are omitted and only the summarized results are given.

The Hollerith system of punched cards and machine calculation (9, 10) was used throughout. The statistical constants calculated were: Mean and its probable error; standard deviation; coefficient of variability; simple correlations between each of the variables and the remaining five variables. From these constants tests of significance were used to evaluate, in a manner similar to that reported earlier (1, 7, 8), the varieties as to their ability to transmit desirable vigor to their progenies. No effort has been made to evaluate soil heterogeneity.

Some of the generalizations derived from these studies are:

(1) Delicious when crossed with Antonovka, Patten 1003, Anisim, Northwestern Greening, Patten 1000, and Patten 1011 produces seedlings below average in vigor. Therefore when Delicious is used in breeding work a careful selection of the other parent is necessary to secure seedlings of desirable vigor.

(2) Jonathan, likewise, to produce vigorous seedlings should be crossed with varieties such as Antonovka and care must be taken to avoid crossing it with varieties such as Salome and Delicious which evidently do not supplement its factors for desirable vigor.

(3) Grimes produces progenies of average vigor when crossed with Antonovka and Northwestern Greening. When used in combination

¹The data for this study were provided by the Pomology Subsection of Iowa State College and represents some 13 years of detailed records covering approximately 5,000 crossbred apple seedlings.

²Journal Paper No. B28 of the Iowa Agricultural Experiment Station.

³This paper is an extract from a thesis submitted to the faculty of the graduate school at Iowa State College, September 1931, in partial fulfillment of the requirements for the degree of Master of Science.

with Nelson Sweet and White Pippin it produces seedlings below average in vigor.

(4) Antonovka, regardless of the other variety used in the cross, generally produces seedlings of average or better than average vigor. It carries this ability to a greater degree than any of the other varieties studied.

(5) Varieties such as Salome, Nelson Sweet, White Pippin and Black Annette, on the other hand, have shown a consistent trend toward production of seedlings of low average vigor.

The vigor rating given above was valuable in itself but since in some instances trees possessing only average vigor would be more desirable orchard trees than those of the greatest vigor, it seemed that a rating of the apple varieties on the basis of their transmission of desirable grade to their progeny would be valuable. The trees in each progeny were rated as to grade. The grades (1) very good, (2) good, (3) fair, and (4) poor were used (3). The percentage of trees in each progeny falling into the various grades shows some striking differences in transmission of desirable factors for grade by the various varieties. The grades "very good" and "good" were combined and the tentative grade classification of the varieties studied, based on their progeny, is as follows:

A. Varieties which produced approximately 75 to 100 per cent of trees grading very good and good, when crossed with other varieties: Antonovka, Ashton (tentatively), and Oldenburg.

B. Varieties which produced approximately 50 to 75 per cent of trees grading very good and good when crossed with other varieties: Delicious, Grimes, King David, Patten 1011 (tentatively) and Geneva 58 (tentatively).

C. Varieties which produced approximately 25 to 50 per cent of trees grading very good and good when crossed with other varieties: Northern Spy, Northwestern Greening, Jonathan, Pewaukee and Anisim; Patten 1000, Patten 1003, White Pippin and Black Oxford (tentatively).

D. Varieties which produced approximately 0 to 25 per cent of trees grading very good and good when crossed with other varieties: Salome, Black Annette (tentatively) and Nelson Sweet (tentatively).

Various measurements of vigor taken at different ages of the tree have been described (3). Simple correlations between each pair of these measurements were calculated. Of the 600 correlations calculated, 562 were highly significant, ($P > .01$), 24 were significant, ($.01 < P < .05$) and 14 were non-significant, ($P \geq .05$) according to the table V. A., R. A. Fisher (4). Though all the correlations were positive they were sufficiently low to indicate that they did not measure the same variable (*i.e.*, they failed to measure the same expression of vigor).

*Approximately is used because in some crosses one of these varieties may have a progeny which will grade more or less very good and good trees than the percentage limits would indicate.

The correlations between different measurements of vigor were statistically different in the various progenies. A summary of the correlation relationships revealed the following facts:

(1) Neither height nor spread is a reliable measure from which to predict the opposite character in the same year or at different years.

(2) Height of tree after 2 or 3 years in the orchard is not a safe basis from which to predict individual tree height values later on, although useful for the prediction of average values for large numbers of seedlings.

(3) Caliper at planting time in the orchard is not a safe basis from which to predict individual values for height, spread, volume and trunk circumference later on, although useful for the prediction of average values.

Comparison of the various measurements of vigor shows that height and spread do not measure the same expression of vigor. Trunk circumference appears to be an unreliable measure of vigor in crossbred apple seedlings where the seedling trees are of many shapes and sizes. From the comparisons made it appears that the volume index⁵ to estimate vigor gives a more nearly correct estimate of vigor than any of the three measures used. This conclusion is based on the following considerations:

(1) It is derived from both height and spread measurements, and thus is not unduly influenced by uncorrelated variations of height and spread.

(2) Many trees grow outward instead of upward and others conversely. Thus a single measurement may not represent the true vigor of the tree.

One of the objections to the volume method is that it fails to make allowance for the density of the tree in the space occupied by the so-called volume. This objection is quite valid but in seedling trees where probably the density of no two trees is the same, it appears as if this error would be very difficult to remove.

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⁵The measurement of vigor termed volume was calculated from the following formula: $\text{Volume} = (\text{Spread}^2) \times (\text{Height} - 2 \text{ feet})$. This formula was developed by H. E. Nichols of Iowa State College.

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Fruit Breeding: A Method of Recording and Analyzing Data¹

By H. L. LANTZ, *Iowa State College, Ames, Ia.*

WHEN a fruit breeding program entails extensive crossing of varieties, and large numbers of seedlings are grown and fruited, record-making becomes a problem. A fruit breeding project worthy of continuity from year to year should be planned so that the records are permanent and clearly intelligible to succeeding workers.

At the Iowa Station, a card system of record-making was used until 1924. These records were designed to record definite information as to the growth, health and productiveness of each individual seedling tree. The system of note taking employed provided a rather intimate study of each tree, but it had the fault of requiring too much time in the orchard. Many descriptive adjectives crept into the records, such as: "nearly," "about," "quite," "o. k.," etc. The information contained in these annually recorded notes was found to be mainly useful as a history of the performance of each tree.

These records were not well adapted to tabulation of results, and were not entirely satisfactory for making progeny studies. Realizing the shortcomings of the system, we finally devised what we have called a "tabulation" system of record making. The method as developed applies not only to the trees, but also the fruits. The system has a distinct advantage in the saving of time in both the orchard and laboratory.

In a single operation, it is possible to do what formerly required laborious note taking, and an equally laborious tabulation of the same notes later on. The tabulation method of record-making meets all the requirements for studying progeny performance in cross breeding work, and sacrifices but little in so far as keeping the history of each individual tree is concerned.

The great saving of time in taking records and the evident increased accuracy of the records is sufficient to justify the method. In the case of fruit breeding studies we have been concerned with progeny performance, and the tabulation method of taking records meets nearly all the requirements for satisfactory analysis.

Further, the records are of such a nature that progenies and individual trees in the progenies will always retain their exact identity. In addition, a zinc embossed label is attached to each seedling tree planted in the orchard. This label includes a record of the location, breeding number and parentage. Such labeling facilitates matters at harvest time, and the labels are a constant source of satisfaction throughout the process of making records.

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BLOOM, YIELD and VIGOR RECORD

Seed Borne.

[illegible]

This record is used from the fifth year on, to record blooming and production, vigor or other characteristics of the individual trees.

As to the records themselves, the worker must decide with considerable judgment how, what, and when the data shall be recorded. When the seedling progenies run into the thousands of trees, the extent and nature of the records must necessarily be limited by taking only essential data unless considerable help is available.

At Ames and Charles City there are upwards of 10,000 seedling trees in the orchard. Obviously to secure annual records on each tree is a large task. The new method entails no note records of any kind, but rather is a system of scoring, measuring or recording consecutively, certain specific characteristics for each tree. The accompanying record sheets indicate what is meant here.

Some of the records taken are based on practiced judgments, as, for instance, grade of tree. *Exact measurements* are also used, particularly on vigor studies. In either case these records are capable of rather critical analysis, and the exact measurements of tree lend themselves to strict statistical interpretation.

Tree measurements are made the first year in the seed bed to secure relative readings on the mean heights of the seedlings of each progeny. Generally the trees stand two seasons in the seed beds and two years in the nursery row. At the end of the second year in the nursery the trees are again measured to secure a second reading of vigor on each progeny. The purpose of such measurements is to get all the data possible on initial vigor and to correlate the relative initial vigor of the progenies with measured vigor after the trees are in the orchard for 5 to 8 years.

The first summer that the trees are in their permanent locations in the orchard each tree is calipered and graded. Records on growth are taken in the late summer or fall. We have found it quite desirable to estimate amounts of growth annually. These estimates are in four classes as follows: (1) very good (18 inches or more terminal growth); (2) good (12 to 18 inches); (3) fair (6 to 12 inches); and (4) poor (little or no growth). These estimates are not difficult to make and afford a complete growth history of each tree from the beginning to the end of the experiment. When the trees reach fruiting age a record of the percentage bloom and percentage crop matured are taken in the spring and fall respectively.

The statistical analysis of the relative vigor of the progenies necessitates rather careful measurements. We have found it convenient to use two men in making measurements, one to hold the measuring pole and the other to make and record the readings.

The trees are measured to the nearest 3-foot interval both as to height and spread. Trunk circumferences are measured 1 foot from the ground and are recorded to the nearest $\frac{1}{4}$ inch. These measurements are all recorded in the columns of the accompanying record sheets in the order of: (1) height, (2) spread, (3) caliper. These measurements do not tell the whole story but are capable of strict statistical analysis.

Such measurements taken after the trees have made 6 to 8 years' growth in the orchard, seem to afford quite reliable estimates of the mean relative statistics of the different progenies and make it possible to determine those parent varieties and combinations of parents which transmit desirable vigor to their progeny.

That trees of the same general vigor and size may differ very markedly in habit of growth and desirability as orchard trees is also recognized. Accordingly we grade the trees into one of four classes, as (1) very good, (2) good, (3) fair and (4) poor. These are judgment grades but nevertheless such a record provides some very reliable and satisfactory data and supplements the statistical interpretations of data very effectively.

By the use of appropriate symbols in the various vigor columns of the record sheets it is possible to combine in a single year's record the essential data as to (1) annual growth, (2) grade of tree, and (3) the measurements of height, spread and caliper.

Every record worth taking should be given a DATE, and all data should be recorded with a sharp hard pencil. This comment may seem trivial, but we have to emphasize these things over and over again to our assistants and it seems worth passing on. Records made with a soft pencil smear up badly. Ink smears if the records become wet.

A tabular system is also used for recording the characteristics of each seedling fruit produced. The external characteristics of size, form, color, and skin are classified and likewise the internal characteristics of color of flesh, firmness, texture, grain, juice, degree of acidity or lack of it, quality, season, and the general desirability of the fruit. After tree and fruit characters are tabulated, it is a simple matter to summate the results and evaluate them.

In conclusion, it may be said that the tabular method of recording tree and fruit characteristics has the *advantage of the accuracy obtained by definitely recording the observed characteristics directly from the trees and fruits*. This type of record-making is capable of expansion and may be devised to study any particular characteristic of the tree or fruit. For the sake of accuracy of observation, only one characteristic of the tree should be recorded at a time, except where measurements of the tree are involved. It is less confusing to study and record grade of tree alone than to make observations on shape of tree and foliage at the same time.

The heterozygous nature of fruit breeding materials has been pointed out by many writers. Since apple varieties are notoriously self-sterile and presumably heterozygous to a greater or less degree for all or nearly all characters or characteristics, and are propagated asexually, "Mendel's law does not have here the same value as for the breeder of self-fertilized crops" (1). Genetic studies as to the mode of inheritance for many characters are difficult if not largely unattainable. Therefore, the fruit breeder, as has often been pointed out, may well confine a large part of his studies to progeny performance to determine the potency of the parent varieties as revealed by

their progenies. It is in this field that the fruit breeder is likely to secure the largest returns. A critical study of progenies yields valuable information as to the relative value of the different parent varieties which have been used in the crosses. The value of definite information as to the transmission of characteristics by the various parent varieties is perfectly obvious. Statistical method, which is dependent upon well arranged and carefully planned methods of taking data, is a most effective tool in analyzing progeny performance, particularly in a study of vigor of tree and size, shape, etc. of fruits.

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The Persistence of Winter Injury in Certain Delicious Hybrids¹

By H. E. NICHOLS and H. L. LANTZ *Iowa State College, Ames, Iowa.*

DURING the last 3 days of October, 1925, a cold wave swept over the North Central States, sending the thermometer at Ames down to —7 degrees F. on October 30. Official temperatures in Iowa ranged from —15 degrees in the northwestern part of the state to 13 degrees at Keokuk. Zero temperatures occurred as far south as southern Iowa and northern Missouri. The minimum temperature for this period was —28 degrees in Montana, while sub-freezing weather was reported from every state in the country, with the exception of Florida, where the minimum was 37 degrees.

Weather conditions in Iowa until late October were favorable for plant growth. Young trees were still growing and the more tender varieties suffered considerable winter injury as a result of the freeze. Trees under 10 years of age of Golden Delicious, Stayman, Jonathan, Grimes, and Delicious showed differential amounts of injury, with Golden Delicious showing the most and Delicious the least. Hardy varieties as Oldenburg, Wealthy, Tolman, Fameuse, and Yellow Transparent showed very little or no injury.

Bark splitting at the ground line was noted soon after the freeze. The cambium or the outer layers of the xylem on the trunks of many young trees showed considerable browning. By spring, however, much of this browning had disappeared. During the spring of 1926, trunk and crotch injury, killing back of terminals, and black heart were noted.

It is estimated that about 5 per cent of the trees of the affected varieties in young orchards throughout Iowa were killed or badly injured. Thirty per cent were damaged to a greater or less extent and 65 per cent were uninjured. Injury to nursery stock was extensive on many varieties.

Although fruit trees in Iowa suffered the most severe damage, injury was reported from 10 other North Central states. The area of greatest damage extended from southeastern Nebraska northeastward through northern Missouri, Iowa, southern Minnesota, Wisconsin, and Michigan. Slight damage was reported from Hot Springs, South Dakota, and portions of Kansas, Illinois, Indiana, and Ohio.

The geographic area in which injury occurred closely coincided with that over which there was a deficiency of —9 degrees or more from the normal October temperatures, with the exception of the northwestern section of this area which included most of South Dakota, North Dakota and Montana. In this section only hardy varieties

¹Journal Paper B-26 of the Iowa Agricultural Experiment Station.

can be grown. They were not injured, even though the minimum temperature over this area was lower than further south.

In the orchards at Iowa State College are 1,553 seedling trees of known parentage with Delicious as one of the parents. These Delicious hybrids include 22 crosses using 19 varietal parents. In 14 of these crosses Delicious is the male parent, in 5, the female parent,

TABLE I—PERSISTENCE AND DEGREE OF INJURY ON CERTAIN DELICIOUS HYBRIDS CAUSED BY THE LOW TEMPERATURES OF OCTOBER 1925. OBSERVATIONS MADE IN JULY AND AUGUST 1930

Other Parent	No. Trees Observed	Percentage of Trees Showing Injury				Injury Index ¹
		None	Slight	Medium	Bad	
Antonovka.....	352	70.5	19.0	6.8	3.7	2.677
Northern Spy.....	285	20.6	38.1	26.9	14.4	9.437
Anisim.....	242	74.4	10.7	5.8	9.1	3.958
Jonathan.....	198	23.2	15.7	20.7	40.4	15.388
Northwest. Greening.	102	29.4	25.5	20.6	24.5	11.096
Black Annette.....	92	53.3	18.5	13.0	14.2	6.728
Pewaukee.....	67	46.3	20.9	13.4	19.4	6.477
Patten 1011.....	60	56.7	23.3	8.3	11.7	5.666
Patten 1000.....	35	83.3	8.3	5.3	2.8	1.971
Salome.....	32	43.7	31.2	9.4	15.7	7.375
Patten 1003.....	31	48.4	22.5	16.1	13.0	6.935
Total number trees...	1496	736.0	324.0	213.0	223.0	
Average per cent.....		49.2	21.7	14.2	14.9	7.263 ± .906

¹Injury index was figured from the formula $\frac{a+b+c+d}{n}$, n equaling the number of trees in each progeny; and a, number of trees with no injury x 0; b, number of trees with slight injury x 5; c, number of trees with medium injury x 12; d, number of trees with bad injury x 30.

and there are 3 reciprocal crosses. These trees are the result of hand pollinations made prior to 1919. The seeds were planted in 1918, 1919, and 1920 and the resultant trees were planted in their present locations in 1924 and 1925. Hence all were subjected to the low temperatures of October 1925.

Only those progenies that contained 30 or more trees were included in this study. These included crosses made with Delicious and the following varieties: Antonovka, Northern Spy, Anisim, Jonathan, Northwestern, Black Annette, Pewaukee, and Salome, and three Patten seedlings that had been selected as parents on account of their hardiness.

In the summer of 1930, very little external signs of injury could be observed. Upon removal of branches that had been formed prior to 1926, however, various degrees of browning in the 1925 and older wood were noted in many branches.

A preliminary study showed that in any one tree the degree of browning was very uniform in all branches. Dorsey (1) made similar observations in a study of winter injury on seedlings of Malinda in Minnesota. Consequently, in this study, data were taken from one branch (formed prior to 1925) from each tree.

The evidences of winter injury showing in these trees ranged from a slight discoloration of the wood to black. In some of the most severely black-hearted branches, wood rotting organisms were growing. For classification purposes the trees were divided into four groups, *viz.*, those showing (1) no injury, and those showing (2) slight, (3) medium, and (4) bad browning.

TABLE II—RELATIONSHIP OF HARDINESS OF PARENT TO THE AMOUNT OF INJURY IN THEIR PROGENIES FROM CROSSES WITH DELICIOUS

Parent Varieties Arranged in Order of Hardiness	Hybrids Uninjured (Per cent)	Hybrids Badly In- jured (Per cent)	Injury Index
Antonovka.....	70.5	3.7	2.677
Anisim.....	74.4	9.1	3.958
Black Annette.....	53.3	14.2	6.728
Pewaukee.....	46.3	19.4	8.477
Salome.....	43.7	15.7	7.375
Northern Spy.....	20.6	14.4	9.437
Northwestern Greening.....	29.4	24.5	11.096
Jonathan.....	23.2	40.4	15.388

The low temperatures of October 1925 caused various degrees of damage to 50.8 per cent of the 1,496 Delicious hybrids examined. Table I summarizes the results. It will be noted that where Delicious was crossed with a hardy variety such as Antonovka or Anisim the hybrids showed much less injury than where more tender varieties such as Jonathan were used in the cross. Of the 352 Antonovka hybrids, 70.5 per cent, and of the 242 Anisim, 74.4 per cent showed no injury, while only 20.6 per cent of the 285 Northern Spy and 23.2 per cent of the 198 Jonathan hybrids were uninjured.

A close relationship existed between the amount of injury found in these Delicious hybrids and the commonly accepted hardiness rating of the parent varieties. In Table II the named varieties that were crossed with Delicious are listed in the commonly accepted order of their hardiness, with Antonovka the most hardy and Jonathan the least. This table also gives the percentages of the hybrids that showed no injury and those showing extensive injury.

Examination of the data in Table II shows a remarkable correlation between the hardiness rating of the parent varieties used in the crosses and the average progeny performance of the different crosses as indicated by the "injury index" and also by the percentage of seedlings in each progeny that showed no injury. These data indicate that the hardiness of a variety (phenotype) may be a good index as to its hereditary makeup with respect to its potency in transmitting those factors which produce rather definite quotas of hardy seedling trees.

In an endeavor to express in one numerical term, the degree of injury found in these hybrids, a summary average figure was used, here called the "injury index." Quisenberry (2) used a similar figure,

called by him the "hardiness index," in measuring the amount of winter damage sustained by wheat. In computing the "injury index" the numerical value of 0 was arbitrarily given to those trees showing no injury, 5 to those showing slight injury, 12 to those showing medium injury and 30 to those badly injured. The number of trees in each line of breeding showing the different degrees of injury were multiplied by their respective numerical values and the sum of the products was divided by the total number of trees. The formula used is stated in the note under Table I. With a mean injury index of all the Delicious hybrids studied of $7.263 \pm .906$ (Table I) there was a range of 13.417 between the most hardy progeny, Patten 1000, which had an injury index of 1.971 and the most tender, Jonathan, where the injury index was 15.388. The injury index of the progenies of the named varieties follows very closely the hardiness rating of the parent varieties (Table II).

After the trees have been exposed to a test winter, the degree of browning of the wood is a suitable index with which to measure the relative hardiness of apple varieties and their progenies. The exact winter hardiness in individual cases is difficult to record with mathematical precision. Nevertheless, the observations recorded here are the best judgment of the observer. Such judgments are believed to provide a means of determining relative hardiness where applied to a large number of trees of different varieties or, as in this study, to various Delicious progenies. The use of an injury index provides an arbitrary means of expressing this relation with one numerical figure.

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The Best Parents in Strawberry Breeding

By G. L. SLATE, *Experiment Station, Geneva, N. Y.*

THIS paper is an attempt to measure the value of different varieties of strawberries as parents in breeding work by comparing the percentages of promising seedlings selected from various populations for further testing. Twenty-eight varieties were used as parents in producing over 13,000 seedlings which first fruited during the years 1925 to 1931. Fifty-six crosses were made of which three were reciprocals.

The crosses were made in the field, the seed was stratified in sand as soon as harvested and planted in the greenhouse the following spring. The seedlings were transplanted once in the greenhouse. In June they were moved to the field where they were grown on the hill system and fruited the following year. During the period covered in this paper, the same observers made all the selections, going over each planting several times during the fruiting season. Selections were made rather freely especially among the very early and very late populations, but none were selected that did not seem to be definitely superior to standard sorts in certain fruit characters. It was not possible to pay much attention to plant characters, although weaklings, unproductive plants, and those with foliage susceptible to leaf-spot were eliminated.

The chief object in making the crosses reported upon in this paper was the production of improved varieties, especially very early, very late, and preserving varieties.

A brief characterization of those varieties not generally known is necessary to explain why certain crosses were made. Clermont, Culver, Caledonia, 4096, 4145, 4734, and 5569 were raised from a cross between Marshall and Howard and as grown at Geneva excelled their parents in most respects. Dutch Evern is a very early and important European sort. Schaubert is a handsome, tough-skinned seedling sent to the Station for trial but not disseminated. Winchester and Wyona are two of the best very late varieties in the Station collections. Howard is, of course, the well known Premier.

The parents, population, and percentage of seedlings selected for further testing are shown in Table I, the crosses being so arranged that all the crosses involving a given variety are together. The crosses in which a variety is used as a seed parent are listed first, followed by the crosses in which the same variety is used as a pollen parent. Immediately following Howard in the table are the crosses in which Howard appeared as a grandparent.

The summary of Table I shows the percentage selected of the total population of all the crosses in which any one variety appears, both as the seed and pollen parent.

TABLE I—NUMBER AND PERCENTAGE OF PROMISING SELECTIONS FROM VARIOUS STRAWBERRY CROSSES

Parents	Number Seedlings Grown	Percentage Selected
Howard x Beacon	57	26.3
Howard x Marshall	365	17.8
Howard x Dutch Evern	925	12.0
Howard x Early Bird	78	11.5
Howard x Vanguard	255	10.2
Howard x Mastodon	282	6.0
Howard x Self	39	.0
Marshall x Howard	767	11.2
Beacon x Howard	417	8.6
Warfield x Howard	169	.6
Clermont x Schaubert	180	11.1
Clermont x Wyona	27	.0
Superb x Clermont	78	12.8
Mastodon x Clermont	42	.0
Caledonia x Schaubert	95	6.3
Caledonia x Pearl	226	5.2
Caledonia x Bliss	235	2.5
Caledonia x Parson's Beauty	330	1.8
Caledonia x 5569	219	1.3
Culver x Pearl	238	5.0
Culver x 5569	228	1.7
Culver x Bliss	234	.4
Pearl x Culver	236	4.2
Schauber x Culver	237	3.8
Missionary x Culver	226	2.2
Wyona x Culver	456	.2
Pearl x 4734	234	6.4
Wyona x 4734	537	4.3
Missionary x 4734	229	3.0
Schauber x 4734	197	2.0
Schauber x 4096	179	2.2
Schauber x 4145	190	1.0
Marshall x Howard	767	11.2
Marshall x Boquet	308	2.9
Marshall x Chesapeake	149	2.0
Marshall x Bliss	416	1.4
Marshall x Joe	341	1.1
Marshall x Delicious (of N. Y.)	228	.8
Marshall x Beacon	29	.0
Howard x Marshall	365	17.8
Warfield x Marshall	185	1.6
Schauber x Marshall	73	1.3
Winchester x Marshall	100	.0
Mastodon x Marshall	19	.0

Parents	Number Seedlings Grown	Percentage Selected
Beacon x Howard	417	8.6
Beacon x Vanguard	244	6.1
Beacon x Early Bird	237	1.7
Beacon x Ozark	229	.8
Howard x Beacon	57	26.3
Mastodon x Beacon	380	.5
Warfield x Beacon	122	.0
Marshall x Beacon	29	.0
Pearl x 4734	234	6.4
Pearl x Culver	236	4.2
Pearl x Bliss	240	2.5
Caledonia x Pearl	226	5.2
Culver x Pearl	238	5.0
Wyona x 4734	537	4.3
Wyona x Bliss	524	.2
Wyona x Culver	456	.2
Clermont x Wyona	27	.0
Warfield x Delicious (of N. Y.)	219	2.8
Warfield x Joe	132	2.2
Warfield x Boquet	154	1.9
Warfield x Bliss	282	1.7
Warfield x Marshall	185	1.6
Warfield x Howard	169	.6
Warfield x Chesapeake	194	.5
Warfield x Beacon	122	.0
Pearl x Bliss	240	2.5
Caledonia x Bliss	235	2.5
Warfield x Bliss	282	1.7
Marshall x Bliss	416	1.4
Culver x Bliss	234	.4
Wyona x Bliss	524	.2
Schauber x Culver	237	3.8
Schauber x 4096	179	2.2
Schauber x 4734	197	2.0
Schauber x Marshall	73	1.3
Schauber x 4145	190	1.0
Clermont x Schaubert	180	11.1
Caledonia x Schaubert	95	6.3
Missionary x 4734	229	3.0
Missionary x Culver	226	2.2
Howard x Vanguard	255	10.2
Beacon x Vanguard	244	6.1
Mastodon x Vanguard	69	.0
Culver x 5569	228	1.7
Caledonia x 5569	219	1.3
Early Bird x Ozark	201	3.4

Parents	Number Seedlings Grown	Percentage Selected
Howard x Early Bird	78	11.5
Beacon x Early Bird	237	1.7
Mastodon x Beacon	380	.5
Mastodon x Vanguard	69	.0
Mastodon x Clermont	42	.0
Mastodon x Marshall	19	.0
Howard x Mastodon	282	6.0
Early Bird x Ozark	201	3.4
Beacon x Ozark	229	.8
Warfield x Delicious	219	2.8
Marshall x Delicious	228	.8
Marshall x Boquet	308	2.9
Warfield x Boquet	154	1.9
Warfield x Joe	132	2.2
Marshall x Joe	341	1.1
Marshall x Chesapeake	149	2.0
Warfield x Chesapeake	194	.5
Total	13282	4.58

SUMMARY

Howard as one parent	3307	11.0
Howard as one grandparent	4406	3.9
Howard as two grandparents	447	1.5
Clermont as one parent	327	9.1
Caledonia as one parent	1105	2.9
Culver as one parent	1855	2.2
4734 as one parent	1197	3.6
Marshall*	1848	1.5
Beacon*	1241	1.8
Pearl as one parent	1174	4.7
Wyonas as one parent	1544	1.6
Warfield as one parent	1457	1.5
Bliss as one parent	1931	1.3
Schauber*	971	2.6
Mastodon*	510	.4

*Not including crosses in which Howard is the other parent.

Examination of the table shows that Howard is the outstanding parent of the entire list. In every cross involving Howard, except that with Warfield, an unusually high proportion of seedlings has been selected for further testing. The crosses of Howard with Beacon and Marshall have been especially successful, although neither of these varieties has given satisfactory results when used in other combinations.

Though this paper does not deal with the inheritance of characters, it may not be amiss to note that the populations in which Howard figures as a parent have a large number of seedlings of which the fruit is very smooth and regular in shape and very glossy in appearance. By far the handsomest strawberries the author has ever seen have been seedlings of Howard. Many of these seedlings hold up in size well to the end of the season.

Howard is much better as a parent than as a grandparent. Of the seven seedlings of Howard used in breeding, namely, Clermont, Culver, Caledonia, 4734, 5569, 4096, and 4145, only the first has given results approaching those obtained by using Howard. Marshall as a parent gave poor results except when combined with Howard. Beacon and Mastodon, likewise generally failed as parents, except in the combinations with Howard, Beacon also combined well with Vanguard, 6.1 per cent of the seedlings of this cross being of sufficient merit for further trial.

A few good seedlings resulted from various combinations with Pearl, but had these not been very late and of high quality, few would have been selected.

Wyona, Warfield, Bliss and Schaubert also were of little merit as parents. Of these only Warfield was crossed with Howard, but even in that combination Warfield was a failure. Schaubert was promising only in the cross with Clermont, where 11.1 per cent of the population were of sufficient merit for further trial.

Other varieties of little promise as parents in the combinations used were Early Bird, except when crossed with Howard, Ozark, Delicious (of N.Y.), Boquet, Joe, Chesapeake, and Winchester. However, not enough crosses were made with these varieties for a fair test and one may only say that they failed in the combinations used. Vanguard combined well with Howard and Beacon, but failed with Mastodon.

Self-Unfruitfulness in *Prunus Tomentosa*

By G. L. SLATE, *Experiment Station, Geneva, N. Y.*

IN 1930 a number of crosses between selections of *Prunus tomentosa* were made. At the same time 11 individuals were selfed to determine the inheritance of certain fruit and plant characters. Inasmuch as most of the crosses were successful and all of the selfs except one failed to set fruit, it was decided to repeat the experiment the following season to determine more definitely the self-fruitfulness or self-unfruitfulness of *P. tomentosa*.

TABLE I—RESULTS OF SELFING PRUNUS TOMENTOSA

1930 Crop					1931 Crop		
Seedling Number	Selfed	Open Pollinated	Selfed	Open Pollinated	Seedling Number	Selfed	Open Pollinated
338	0	Light	—	—	148	0	Full
688	0	Light	0	Light	149	1 fruit	Full
689	0	Medium	0	Medium	150	0	Full
912	0	Medium	0	Light	151	0	Full
1,058	0	Medium	0	Light	153	0	Full
1,072	0	Medium	—	—	155	2 fruits	Full
1,156	0	Medium	—	—	156	0	Medium
1,163	0	Medium	0	Light	157	0	Full
1,165	0	Medium	—	—	158	0	Full
1,172	0	Light	0	Light	159	0	Full
508	Light	Light	Light	Light	160	0	Full
507	—	—	Light	Light	161	0	Full
506	—	—	Light	Light	162	1 fruit	Full
505	—	—	Light	Light	398	0	Light
					1,077	0	Light
					1,171	0	Medium
					H. P. 1371	0	Medium

Of the 31 individuals tested in 1931, four were of the "yellow foliage" type previously described (1). These were included because the only plant to set fruit in 1930 when selfed was of this type, and it was thought that there might be a possible correlation between this plant type and self-fruitfulness.

Two large bags of parchment paper about 30 by 19 inches and two 10-pound bags were used on each plant. It was not feasible to count the number of flowers in each bag, but since *P. tomentosa* is very floriferous, probably a few thousand flowers on each plant were bagged. The crop within the bags was compared with the crop on the open-pollinated branches of the plant, the yields being designated by the terms light, medium, and full.

The results as shown in Table I indicate that *P. tomentosa*, with the exception to be noted, is self-unfruitful. The few fruits resulting from selfing in 1931 are probably the result of contamination, since the pistils occasionally protrude from the buds before anthesis and some of these may have been overlooked.

It is interesting to note that the four self-fruitful plants, namely, Nos. 505, 506, 507, and 508 at the bottom of Table I, which all set fruit as well in the bags as on the open-pollinated branches outside of the bags, belonged to the type previously described (1) as a "yellow foliated type." This type is characterized by having foliage of a distinct yellowish cast, with the leaves slightly smaller than those of the normal type. The plants are upright, nearly vase-shaped, and smaller than the normal type.

Seedlings raised from No. 508 indicate that this individual, at least, is heterozygous for albinism. In 1930, 148 seeds were obtained by selfing this plant, and of the 64 which germinated, 7 were albinos. This proportion indicates that more than one genetic factor may be involved in the production of these albinos.

In order that poor pollen might not be blamed for the failure of the plants to set fruit when selfed, germination tests were made on a 2 per cent agar, 10 per cent sugar medium. In every case excellent germination and long pollen tubes were obtained.

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Chromosome Behavior as a Factor in Berry Breeding

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IN plant and animal breeding it is not always possible to find the most desirable characters among prospective parents that are closely related genetically. The attempt to combine desirable features from groups that are not closely related frequently results in high sterility in the first generation offspring. Under certain conditions this situation may be spontaneously overcome by a doubling of the chromosome number to give a relatively fertile hybrid in the second generation.

One of the berry crosses made at the Texas Station illustrates the attempt to combine the desirable characters of distinctly related groups. The wild dewberry of East Texas and Louisiana, *Rubus rubrisetus*, is vigorous, prolific and very resistant to the prolonged drought and heat of the summer season. Selected plants were crossed in 1912 by the late Helge Ness (3, 4) with pollen from a red raspberry plant of the Brilliant variety, representing an entirely different species, *R. ideaus* var. *strigosus*. The parental species in this case were diploid, with seven pairs of chromosomes. The 21 first-generation plants that reached maturity were almost completely sterile. The few seeds obtained produced plants that were similarly sterile. The following year seed from open-pollinated flowers were again sown, with 280 plants resulting. Five of these 280 second-generation plants were very similar in appearance and were fertile. Longley and Darrow (2) studied the progeny of one of these plants and found 14 instead of 7 pairs of chromosomes. There was slight irregularity during the reduction division. It seems quite likely that these 5 fertile plants were sibs, possibly all from seed of the same fruit, and that chromosome doubling occurred in only one of the 21 plants of the first generation. This assumption is strengthened by the fertility of their progeny. In the third generation there were 581 highly fertile plants of which 8 individuals were selected for propagation and further breeding. These 8 plants which are quite similar in appearance have received the name of Nessberry.

Subsequent attempts to improve the Nessberry by outcrossing have involved both quantitative and qualitative relationships among the chromosomes. Since size of berry is dependent upon seed development, which, in turn ordinarily depends upon the fertility resulting from regular chromosome behavior, it can readily be seen that chromosome associations are of the utmost importance in securing a commercial variety.

Outcrosses of the Nessberry, with later inbreeding, have been as follows:

No. 1. Nessberry X Hailsham red raspberry (third generation).

No. 2. Nessberry X Early Harvest blackberry (fourth generation).

No. 3. Nessberry X Dewberry parent (second generation).

No. 4. Nessberry X Brighton red raspberry (second generation).

It will be noted that in each case the tetraploid mother has been crossed with a diploid, giving triploid families with 21 chromosomes, an unbalanced number. These first generations, with the exception of a few plants very like the mother were almost completely sterile, as might be expected.

In addition to the sterility due to the triploid condition, there is a further cause for sterility of another type in the second cross, involving the Early Harvest blackberry, because of the introduction of a group of chromosomes from a distinct species, *R. laudatus*. Both the Brighton and Hailsham varieties are probably closely related to the Brilliant red raspberry parent of the Nessberry. In two of the crosses there has been considerable opportunity for an increase in homozygosis through inbreeding, which means an increase in chromosome compatibility resulting in increased fertility.

Buds from 26 plants of the third generation of the cross Nessberry X Hailsham have been examined cytologically. Two have been found to be diploid, the remainder tetraploid. The second generation plants from which seed was saved have evidently been those having either a diploid or tetraploid chromosome balance and were therefore relatively fertile. With chromosome balance re-established, we still have specific differences among the chromosomes which relate to the degree of fertility. Of the 162 plants in this third generation, approximately half are completely fertile, while the remainder exhibit various degrees of sterility.

Both of the diploids in the above population have been classed as having reduced fertility. Seven pairs of chromosomes are found at diakinesis and first metaphase. Some lagging is found at both anaphases. Partial sterility is here evidently due to irregularity of chromosome behavior resulting from association of chromatic material from diverse species. Since these plants have the diploid chromosome number, there is greater opportunity for irregular behavior from this cause than in the tetraploid.

Of the tetraploids examined 16 exhibit complete fertility, 6 show a reduction in fertility and 4 have been classed as sterile. Among the completely sterile plants, the irregularity varies from a complete disintegration of the pollen mother cells to almost normal behavior, with 2 plates of 14 chromosomes at the metaphase of the second division. The resulting pollen is poorly developed. In the partially fertile plants the irregularities are less marked. Fourteen pairs of chromosomes are usually in evidence at diakinesis and at the first metaphase. There is often an unequal division of the chromosomes at this time resulting in malformation of the pollen grains.

An examination of the pollen mother cells of those plants recorded as completely fertile discloses slight irregularities in cer-

tain plants. It would seem that such irregular behavior was not of sufficient importance in the egg mother cells to interfere greatly with their normal functioning.

While the second outcross, that with the Early Harvest blackberry is now in the fourth generation, with the additional opportunity for selection for fertility, there is a smaller percentage of completely fertile plants than in the preceding cross. This is undoubtedly due to the fact that the chromosomes introduced by the blackberry parent are less closely related to those of the Nessberry than the germinal material introduced by the raspberry cross. The seven plants examined cytologically from this fourth generation are all tetraploid. Diploids may, of course, be present that have not as yet been discovered. Cytological irregularities are similar to those of the preceding cross.

Sterility of the backcross plants (Nessberry X Dewberry) is evidenced by the poor germination of seeds to produce the second generation. Only 3 of the 39 plants of this second generation are completely fertile. All of the 4 plants examined cytologically are diploid. This sterility is likely due to the presence of chromosomes from the original red raspberry source. Since the plants are diploid the functional balance is seriously interfered with. The situation here is comparable with that of the original cross where complete sets of dewberry and raspberry chromosomes were present. Fertility in the original cross was secured only through a doubling of the entire chromosomal complement to give a double diploid. It is evident that in the backcross under consideration fertility is possible through a preponderance of chromosomes of the dewberry type. The 3 fertile plants are good dewberry types and it is possible that the chromosomes are all of dewberry source, neglecting the possibility of crossing-over with chromosomes from a raspberry source during meiosis in the Nessberry.

Germination of F_1 seed of the cross Nessberry X Brighton red raspberry was also very poor, only 8 second-generation plants having survived to maturity. The single plant examined cytologically proved to have the tetraploid chromosome number, which is evidently conducive to fertility since 3 of the 8 F_2 plants are completely fertile.

In addition to chromosome doubling and interspecific incompatibilities, the occurrence of maternals is a third factor of importance in berry breeding. Evidence from these and other crosses by Professor Ness indicates that the appearance, in crosses, of plants precisely like the mother is not uncommon. It is likely that certain of the tetraploids exhibiting complete fertility may be of this type. East (1) has shown that in the related genus, *Fragaria*, maternals are produced by the doubling of the haploid chromosome set in the egg. If this occurs in material as heterozygous as these *Rubus* hybrids, considerable segregation would still result.

The crosses under discussion emphasize the necessity of complete fertility resulting from chromosome compatibility as a pre-

requisite to the successful combination of desirable characters from diverse sources, in berry breeding. This may be attained by utilizing cases of chromosome doubling and the appearance of maternals from heterozygous parents and by inbreeding with selection for fertility as well as for the combination of morphological characters desired.

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Self and Cross Fertility of Red Raspberry Varieties¹

By MAX B. HARDY,² *State College of Washington, Pullman, Wash.*

ALTHOUGH no self or cross sterility difficulties in pollination are reported by growers of red raspberries, the poor results obtained in 1929 in the red raspberry breeding work carried on coöperatively between the Agricultural Experiment Station at Pullman, Washington, and the Western Washington Experiment Station at Puyallup, Washington, led to the belief that this factor might have played some part in reducing the number of seeds set. Definite information was not obtained, however, until the raspberry blooming and fruiting season of 1931.

Such factors as pollen viability and method of hand-pollination are known to have considerable influence on the setting of seed. True cross and self-sterility enter into the consideration only when these two factors are known to have a minimum of influence. The method of hand-pollination used has been outlined in another paper (2) and need not be considered here again except to make note of the results obtained in 1931. In 29 crosses using six varieties, a total of almost exactly 800 flowers was pollinated and an estimated number of 42,000 seeds was set. In determining the percentage of a normal set which this number of seeds represents, fruits of each variety except King were picked and the average weight per fruit and the average number of seeds per gram weight of fruit of each variety were calculated. The deviation from the normal for the hand-pollinated fruits was then readily calculated since the number of these fruits and their total weight were known. On this basis approximately 83.0 per cent of a normal set was obtained leaving but 7.0 per cent to be attributed to poor technique, lack of viability of pollen, and cross or self-sterility.

Microscopic examination of the pollen of the six varieties used, namely, Cuthbert, King, Marlboro, Antwerp, Latham, and Lloyd George, afforded some information regarding pollen viability. In addition pollen was examined after it had been allowed to germinate in hanging drops of a 10 per cent glucose solution. It is possible that the glucose solution did not give the percentage germination of the good pollen that might be expected with a sucrose solution, but the results are, nevertheless, comparable for the six varieties considered here. For these tests the pollen was obtained from flowers blooming under paper sacks and brought immediately to the laboratory. Striking differences were noted in the type of pollen produced by the different varieties. These are presented in Table I.

It is evident that there is considerable variation in the percentage of viable pollen produced by the different varieties. The percentage

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is rather low in most cases, but is adequate to obtain a full set of seeds if sufficient pollen is applied during hand-pollination. This was assured by applying pollen to each flower for at least 3 days in succession while the pistils were receptive.

TABLE I—RED RASPBERRY VARIETAL POLLEN DIFFERENCES IN VIABILITY

Variety	Per cent Normal Appearing Pollen	Per cent Normal Pollen Germinated ¹	Per cent Total Pollen Germinated	Remarks
Cuthbert...	10.0	75.0	7.5	Pollen tubes short, slender, and slow growing.
King.....	50.0	70.0	35.0	Pollen tubes long, fairly thick
Marlboro...	65.0	30.0	19.5	Pollen tubes short, slender
Latham...	60.0	25.0	15.0	Pollen tubes long and slender
Antwerp...	90.0	80.0	72.0	Pollen tubes fairly long and fairly thick
Lloyd George...	95.0	55.0	52.3	Pollen tubes variable in length, fairly thick

¹Germinated in an approximately 10 per cent glucose solution.

The data showing the effect of the technique of hand-pollination on the setting of seeds are presented in Table II.

It is evident that a fairly large percentage of the fruits set was normal. In fact, only 214 out of the 794 fruits set were below normal in the estimated number of seeds produced. This, in addition to the fact that some sub-normal fruits were produced in nearly all the crosses, indicates that poor technique in hand-pollination did affect the setting of seeds. Such factors as faulty emasculation, failure to apply sufficient pollen, and failure to apply pollen at the correct time would be sufficient to produce the results obtained.

Although the numbers of fruits produced is too small to permit final conclusions, it is probable that the evidence fairly indicates the true facts. With this in mind it is not possible to discover more than one cross the results of which might possibly be explained by at least partial cross-sterility. This is the cross of Cuthbert x Latham which gave 31 sub-normal fruits averaging .72 g. and only 14 normal fruits averaging 1.62 g. In the crosses using the King variety as the pistil parent similar evidence is apparent but must be discarded because the application of pollen after emasculation was delayed longer than advisable.

Seven crosses show a larger number of seeds set following hand pollination than the estimated number which would have been set had those flowers been open-pollinated. Although the value of Lloyd George and Cuthbert as pollenizers is indicated, the differences are very small as a whole, and are due probably to the inevitable errors of the method of calculation rather than to some other factor. Some

other of the values presented in the last two columns in Table II are possibly as much below the true relationship between the number of

TABLE II—NUMBER OF NORMAL AND SUB-NORMAL FRUITS PRODUCED AND APPROXIMATE NUMBER OF SEEDS SET BY HAND POLLINATED FLOWERS

Pistil Parent	Pollen Parent	Number Fruits Set ²	Normal Fruits		Sub-normal Fruits		Number Seeds (Estimated)	
			No.	Average Wt. (Gms.)	No.	Average Wt. (Gms.)	Obtained	Normal
Cuthbert....	King	47	20	1.60	27	0.97	2093	3698
	Marlboro	34	24	1.84	10	1.16	2010	2675
	Latham	45	14	1.62	31	0.72	1624	3541
	Antwerp	28	26	2.20	2	0.95	2129	2203
	Lloyd							
	George	48	47	2.29	1	1.00	3923	3777
King.....	Cuthbert	34	33	2.41	1	1.00	2905	2675
	King	20	15	1.77	5	1.08	— ¹	— ¹
	Latham	8	4	1.63	4	0.65	—	—
	Antwerp	10	4	1.75	6	0.60	—	—
	Lloyd							
	George	25	18	1.35	7	0.83	—	—
Marlboro...	Cuthbert	9	2	1.65	7	0.79	—	—
	Mixed	15	—	—	—	—	—	—
	King	28	19	2.28	9	1.08	1228	1224
	Latham	21	12	1.58	9	0.84	614	918
	Lloyd							
	George	27	21	1.74	6	0.93	977	1180
Latham.....	Cuthbert	20	18	2.09	2	0.35	889	874
	King	21	11	1.87	10	0.78	685	1015
	Antwerp	25	16	1.94	9	0.99	964	1207
	Lloyd							
	George	25	15	1.75	10	0.62	784	1207
	Cuthbert	34	22	2.26	12	1.15	1676	1643
Antwerp....	Latham	15	9	1.93	6	1.05	571	725
	King	20	20	2.23	0	—	930	970
	Latham	28	23	2.34	5	1.38	1266	1357
	Lloyd							
	George	28	22	2.21	6	0.90	1124	1357
	Cuthbert	28	28	2.44	0	—	1427	1357
Lloyd George	King	27	17	1.88	10	1.18	1208	2120
	Marlboro	18	13	1.83	5	1.00	995	1414
	Latham	47	42	2.38	5	0.84	2869	3691
	Lloyd							
	George	26	22	3.17	4	1.50	2091	2042
	Cuthbert	48	43	2.71	5	1.26	3388	3769

¹No basis for estimation available.

²Represents all the flowers hand pollinated except those injured by insects, disease, or mechanical means.

seeds set by hand-pollinated and open-pollinated flowers as the above noted seven crosses are above the expected relationship. The nature of the data precludes the possibility of determining this fact, however. It is believed that the inconsistencies noted do not detract from the reliability of the estimations presented.

It is concluded from the facts presented here that the varieties studied show complete or almost complete self and cross fertility. This is in agreement with Hooper (1) who reports that English varieties of red raspberries are self-fruitful, and with Chandler (3) who reports that experience with plantings of one variety indicates that all the common varieties of red raspberries are self-fruitful. The viability of the pollen produced by the different varieties must be considered in hand-pollination work and sufficient pollen applied to the pistils at the correct time to make certain that each pistil is supplied with at least one good pollen grain. The larger the amount of pollen that is applied the more certain it is that a set of seeds will be obtained. This places almost the whole of the responsibility for the failure of seeds to set on the technique used in the hand-pollination of the flowers.

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Red Raspberry Pollination Technique¹

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THE breeding of red raspberries has been carried on at the Western Washington Experiment Station at Puyallup, Washington, as a co-operative project between that Station and the Agricultural Experiment Station at Pullman, Washington, since the spring of 1929.

The general method used in the hand pollination of fruits was followed in the spring of 1929 in making the crosses. The small number of seeds obtained that first year, however, emphasized the need of a more satisfactory technique, and the need of further study of the influence of self and cross fertility of the varieties on the setting of seeds. With a view to obtaining additional knowledge concerning these problems notes and data were collected the two succeeding years which have aided in clearing up some of the difficulties at first experienced. The data pertaining to self and cross-fertility studies are reported in another paper (1).

Since the lack of experience in making raspberry crosses may have been an important factor in causing the poor results in 1929 the procedure followed that year was repeated the following year in a portion of the crosses. In addition, certain variations were applied to such possible factors as (1) the type of covering for the flowers, (2) the time and method of emasculation, (3) the interval between emasculation and application of pollen, and (4) the method of obtaining and applying pollen. The aim of this paper is merely to outline the technique of hand pollination found most successful.

The flowers to be pollinated were selected on shoots on which there were six or seven that had reached approximately the same stage of development. All farther or less advanced flowers were removed. The flowers to be pollinated were selected so that the flower most advanced in development was showing no more than the initial splitting apart of the sepals. When the blossoms were emasculated just as or before the petals were beginning to show, none of the anthers had begun to shed pollen, as indicated by microscopical examination of the anthers and by the total failure of unpollinated lots of emasculated flowers to set seeds. This is in accordance with the results reported by Wellington (2). Emasculation was accomplished by cutting around the stem of the flower bud with a sharp scalpel while holding the inverted bud between the thumb and forefinger, the cut being made about half way between the stem and the largest circumference of the bud, as shown in Fig. 1. The cut is thus made just below the point of attachment of the stamens and petals on the receptacle and

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the sepals, petals, and stamens can be readily slipped off in toto over the pistils.

The emasculated flowers were then covered with a white paper sack of a convenient size fastened tightly around the base of the fruiting shoot. Cheesecloth gave no better results than did opaque manila bags and was much more difficult to manipulate. A spring

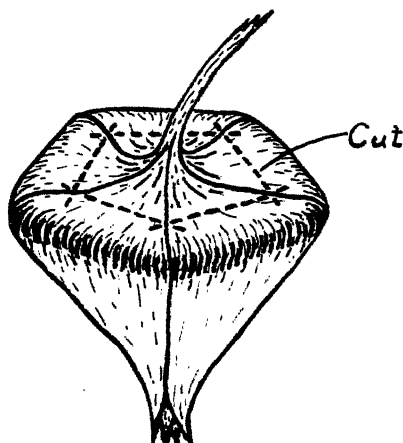


FIG. 1. Semi-diagrammatic sketch of red raspberry and showing the place at which the cuts should be made in emasculation. Approximately $\times 4$.

clip clothespin was found quite suitable for fastening the bags since the latter could be folded and clipped or removed repeatedly and easily.

The flowers from which pollen was obtained for either cross or self pollination were covered with a paper sack before any had opened. These flowers bloomed naturally under the sacks, thus allowing the pollen to develop normally. When pollen of a particular variety was required, a sack covering a shoot of that variety was removed and a number of open flowers with dehiscing anthers picked off with a pair of tweezers and placed in a small tin box marked for that variety alone. These flowers were then carried to the emasculated flowers to be pollinated, the paper sack over these latter removed, and the anthers of the pollen parent flower brushed lightly over the pistils. This pollination was done from 2 to 5 days after emasculation, depending upon the development of the pistils, and every day thereafter until the pistils began to turn brown, indicating that the receptive condition had passed. The receptive condition of the pistils was determined after a little experience without the use of even a pocket lens since at that stage of development the stigmatic surfaces become split into small forks, which gives them a fuzzy appearance.

Pollination as soon as possible after this splitting occurs is to be recommended since much delay was found to result in the failure of many or any seeds to set.

Self-pollinated flowers were not emasculated, but were allowed to bloom normally under paper sacks. A flower of the same variety which was blooming and shedding pollen under another sack was used to spread the pollen over the pistils. Selfing after emasculation by the method used in the crosses gave similar results to selfing without emasculation, indicating that emasculation as practiced had little or no deleterious effect on the setting of seed.

Varieties differ in the number of flowers per shoot which reach approximately the same stage of development at any one time. Six or seven flowers per shoot, however, seems to be the usual maximum number sufficiently uniform to be emasculated on any one day. Emasculation at more than one time increases the number of times which a particular shoot must later be visited for pollinating the less uniformly developing flowers and this, of course, is not desirable.

The foregoing procedure has several advantages, among which the following are the most important: Time and labor are saved in obtaining uncontaminated pollen and in the actual work of pollination. The pistils are also uncontaminated and the method of emasculation has little apparent effect upon their normal development. The success of the method is indicated by the results obtained in 1931 when an estimated number of 42,000 seeds were obtained from approximately 800 hand pollinated flowers representing 29 crosses and selfings.

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A Preliminary Report on the Breeding of Vinifera Grape Varieties

By ELMER SNYDER, *U. S. Department of Agriculture,
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THE breeding of *Vitis vinifera* grape varieties was started at the United States Department of Agriculture Experiment Vineyard near Fresno, California, in 1923. Though the number of seedlings fruiting to date is limited, some interesting results have been obtained.

The main objects sought were to produce more seedless varieties and better table and raisin varieties. The breeding for seedless grapes has received most of our attention. The desire of the public for seedless table grapes is shown by the remarkable increase in Sultanina (Thompson seedless) shipments from almost nothing to an average of approximately 4,500 carloads each year for the past 5 years.

In America considerable breeding work has been done to develop improved varieties from our native species, and in hybridizing American and Vinifera varieties to secure improved quality in grapes suited to the eastern and southern states (5, 7, 9, 10, 11, 12, 13, 16). In France (4) some breeding of Vinifera grapes has been done for the production of better table varieties but principally for the production of wine type grapes. In 1828 Louis and Henry Bouschet started their breeding work with wine grapes with the definite object of infusing the intense color of the Tinto into the heavy producers of southern France. How well they succeeded is shown by the varieties Alicante Bouschet, Petit Bouschet, and Grand noir de la Calmette. These varieties stand out commercially as the result of breeding work for a specific purpose. The breeding for seedless grapes was attempted in England (1, 2, 3) as early as 1875. Though some seedless grapes were produced, none appeared to be of commercial value. Since the Department started the grape breeding work in 1923 Stout (14) has reported on the production of a seedless grape by using the seedless Sultanina rosea as the male parent. Very little breeding work has been done anywhere, however, for the specific purpose of producing seedless Vinifera grapes.

The various steps used in the actual crossing work have been similar to those used by other grape breeders (5, 8, 9). The male blossoms desired were bagged before any blossoms on the cluster were open. The anthers of the female parent were removed before the petals showed any splitting at the base, and the clusters bagged. At the time of pollination the bagged male clusters were removed from the vine and brushed over the emasculated female cluster. The remainder of the male cluster was then inclosed in the bag along with the pollinated female cluster. This method was tested in 1923, when 632 blossoms were emasculated and sacked without pollination. Only three small berries were produced, two of which were seedless, while

TABLE I—A PRELIMINARY SUMMARY

Parentage	Year	No. Blossoms	No. Berries Set	No. Seeds Obtained	No. Plants Grown	No. Fruited	Stamens	
							Up-right	Re-flex
Gros Guillaume x Black Monukka.....	1923	50	11	17	9	9	9	—
Rodites x Black Monukka....	1923	50	10	14	1	1	1	—
Alexandria x Black Monukka..	1926	944	155	288	54	18	15	6
Alexandria x Sultanina.....	1926	1,168	135	210	6	2	2	—
Alexandria x Sultanina rosea..	1926	475	212	262	11	5	5	—
Alexandria x Panariti.....	1926	564	73	130	33	20	16	6
Alexandria x Corinthe blanc..	1927	200	42	72	19	1	—	1
Alexandria x Corinthe rose....	1927	200	81	212	35	1	—	1
Alexandria x Alicante Bouschet.....	1926	464	119	112	27	14	12	2
Alexandria x Damas Rose.....	1926	411	51	73	21	7	7	—
Alexandria x Grand noir.....	1926	612	124	93	17	10	9	1
Alexandria x Malaga.....	1926	445	93	186	37	20	16	4
Olivette Blanche x Olivette noir.....	1926	410	134	57	41	9	8	1
Olivette Blanche x Muscat Hamburg.....	1928	600	227	173	26	—	—	—
Muscat Hamburg x Black Monukka.....	1928	100	50	125	29	—	—	—
Pizzutella x Black Monukka..	1928	95	51	67	24	—	—	—
Damas rose x Black Monukka..	1929	80	47	74	44	—	—	—
Ohanez x Black Monukka.....	1930	60	25	70	27	—	—	—
Muscat Hamburg x Panariti...	1929	100	19	36	19	—	—	—
Vigne de Zericho x Rodites....	1929	150	56	85	52	—	—	—
Rodites x Gros guillaume.....	1930	60	27	46	5	—	—	—
Total.....		7,238	1,742	2,402	537	117 ¹	100	22

¹Five seedlings with reflex stamens did not set fruit.

one contained one seed, only one cotyledon of which was filled. Though this may indicate the possibility of producing some selfed seedlings by this method, the probability is not great.

The seeds were collected in the fall when the fruit was starting to dry on the vines, were cleaned, dried, and kept in a dry condition until planted the following January. The seeds were planted in flats under greenhouse conditions. When the young seedlings were from 2 to 3 inches high they were placed directly in gallon cans and grown one summer under a lath house. Growth of from 3 to 4 feet with a strongly developed root system was obtained in one season from seed under these conditions. The seedlings when 1 year old were planted directly in the vineyard. Less than 1 per cent of the seedlings have been lost when handled in this manner. Some have fruited the third summer from the planting of the seed, but usually not until the fourth.

A condensed summary of the results to date is shown in Table I. Twenty-one crosses have been made. Seven thousand two hundred thirty-eight blossoms were emasculated and pollinated, resulting in

OF BREEDING VINIFERA GRAPE VARIETIES

Flower and Fruit Characters											
Fruit									Early	Medium	Late
White-yellow	Light Red	Dark Red-purple	Black	Seedless	Round	Ob-long	Oval	Elongated Oval			
-	-	-	9	1	-	-	9	-	3	6	-
1	-	-	-	1	-	-	1	-	-	-	1
10	-	8	-	-	2	4	2	4	9	3	-
2	-	-	-	-	1	-	1	-	-	2	-
3	2	-	-	-	1	-	3	1	2	3	-
10	-	10	-	-	3	-	7	7	10	7	-
1	-	-	-	-	1	-	-	-	-	1	-
1	-	-	-	-	-	-	1	-	-	1	-
-	-	-	14	-	4	-	10	-	5	7	2
5	2	-	-	-	1	1	3	1	2	4	-
-	-	-	10	-	4	-	5	1	6	3	1
20	-	-	-	-	6	-	13	1	5	14	1
6	-	3	-	-	-	-	2	7	-	2	7
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-

1742 berries, a set of approximately 24 per cent, yielding 2402 seeds which have produced 537 seedlings for vineyard planting. The percentage of germination obtained was 22.4. One hundred twenty-two seedlings, representing 13 crosses, have blossomed and 117 have fruited. Five seedlings which blossomed failed to set fruit. In all cases both parent varieties had upright stamens. Twenty-two or 18 per cent of the F_1 generation seedlings have shown reflex stamens. A slightly higher percentage of reflex stamens were obtained at Geneva by Hedrick and Anthony (9) when both parents had upright stamens. Varieties evidently differ in the ratio of reflex stamens appearing in the seedlings. Gros Guillaume by Black Monukka gave no reflex stamens while Alexandria by Black Monukka gave five upright stamens to two reflex. Wellington (16) also noted this variation, some varieties, especially Muscat Hamburg, appearing to be homozygous for the character of upright stamens.

Various color combinations have been used. White by white has produced. The gradations in size are well shown by some of the seedling red has produced nine white and four light red seedlings. White

by dark red has produced 26 whites and 21 dark reds. White by black has produced 24 blacks and no other colors. In the last case the two black varieties used as male parents, Alicante Bouschet and Grand noir, may be homozygous for this color. Black by purple black has produced only black seedlings.

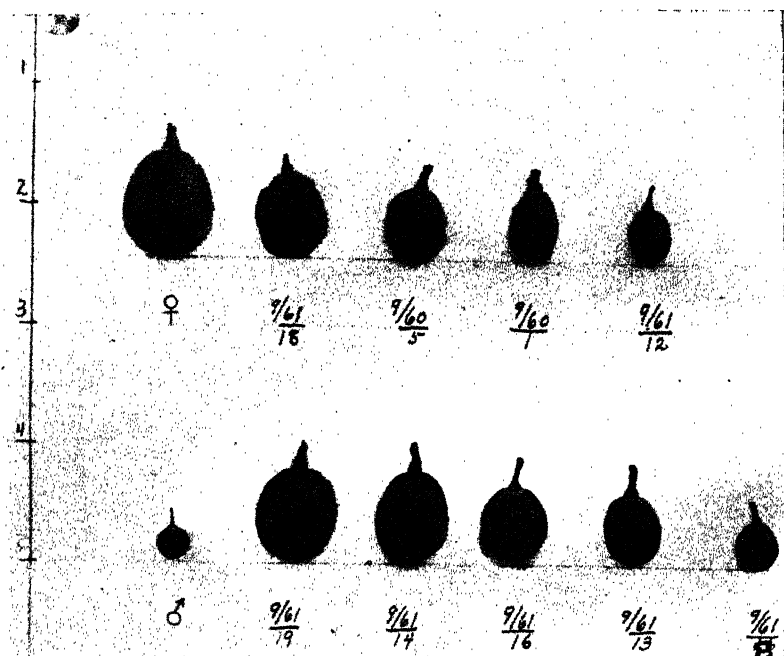


FIG. 1. Representative Berries from Alexandria x Panariti cross.
(Indicating various gradations in size)

In shape of berry the seedlings tend to resemble the parent forms with a predominance of the oval forms typical of many vinifera varieties. In size various gradations between the parents have been produced. The gradations in size are well shown by some of the seedlings produced from the Alexandria by Panariti cross shown in Fig. 1. Crossing large- by small-berried varieties represented by Alexandria x Panariti have produced seedlings with fruit of various sizes. None of the seedlings was larger than Alexandria and none smaller than Panariti. Large- by medium-sized fruit varieties (Gros Guillaume x Black Monukka) have produced mostly medium-sized fruit in the seedlings. Large- by large-fruited varieties, (Alexandria x Malaga), have produced seedlings ranging from medium to large. The lady-finger types (Olivette Blanche x Olivette noir) gave a preponderance of elongated oval types in the seedlings. Size is an important consideration in commercial table grape production. It seems from the

limited data available that large-fruited seedlings can be obtained by using mainly large-fruited parent varieties.

In season of ripening the seedlings tend to resemble the parent varieties. The trend, however, has been toward earliness rather than lateness. In flavor, so far the typical muscat flavor of Alexandria has not been produced in any of the seedlings.

As previously stated, the production of seedless varieties has received the most attention. To date, six seedless varieties, Black Monukka, Sultanina, Sultanina rosea, Panariti (black Corinth), Corinth the rose, and Corinth blanc have been used as male parents in various crosses.

Many of the seedlings resulting from these crosses have not fruited. The possibility of obtaining seedless varieties in the F_1 generation seedlings by using a seedless male parent has, however, been demonstrated. As a result of the first crosses made in 1923 using Black Monukka as the male parent with both Gros Guillaume and Rodites, three seedless hybrids were obtained from 10 seedlings grown. Later crosses have not been so fortunate, since 54 seedlings of the 57 fruiting to date having one parent seedless have contained seeds. Of the crosses fruited to date one seedless progeny resulting from Gros Guillaume \times Black Monukka appears to have possible commercial merit. It is somewhat similar to Black Monukka but apparently its berries adhere to the pedicels much better. Further testing is necessary before its merits can be determined. Interesting fruit has been obtained from several other crosses.

The Vinifera grape breeding work of the U. S. Department of Agriculture has been carried on for only 8 years and on a limited scale. The securing of three seedless crosses as well as other interesting grapes during that time is an encouragement to continue and broaden the scope of the work. With the production of more F_1 seedlings, using seedless male parents, and back crossing, it is believed that additional valuable commercial table grape varieties having the seedless character can be obtained.

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Growth of Concord Grape Cuttings in Relation to Vigor, Chemical Composition and Relative Position on the Cane

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THIS investigation was started, (1) to determine if there is any noticeable difference in the vigor of vines the first year, obtained from canes grown on vines of high, medium and low vegetative vigor; (2) to determine if the cuttings from different regions of canes of similar vegetative vigor produce vines differing in vigor; (3) to determine if there is any marked difference in the carbohydrate and nitrogen composition of canes of noticeably different vegetative vigor; and (4) to determine if there are marked differences in the carbohydrate and nitrogen composition of the different regions of canes of similar vegetative vigor.

Cuttings of the Concord grape were prepared from strongly vegetative, moderately vegetative, and weakly vegetative canes growing on vines of the corresponding vigors. The strongly vegetative canes were produced by limiting healthy, young, non-bearing vines, growing in a fertile loam soil, to two shoots each. The moderately and weakly vegetative canes were obtained by selecting suitable canes from mature bearing vines. The total length of the cane growth which is in agreement with the caliper measurement, was used as an index of the relative vigor.

Within a week or two after the weather had been sufficiently cold to cause the dropping of all leaves, the canes were cut off near their point of origin, measured, and made into cuttings according to their respective lengths. From 5 to 20 representative canes were used in preparing samples for chemical analyses. Both years the strongly vegetative canes were cut into 12 equal parts; the moderately vegetative canes were cut into 9 parts the first year and 8 parts the second year; and the weakly vegetative canes were cut into 4 parts both years. The corresponding sections of the canes of similar vigor constituted a sample. The separate samples were washed, dried of apparent moisture, weighed, cut into small pieces, and refluxed a few minutes with boiling 95 per cent alcohol to which a small amount of calcium carbonate had been added. These samples, which represented the 12 sections of the highly vigorous canes, the 8 or 9 sections of the moderately vigorous canes, and the 4 sections of the weakly vegetative canes were then analyzed for free reducing substances, alcohol soluble acid hydrolizable substances, and soluble and insoluble nitrogen.

The canes that furnished cuttings for the field studies were cut in a similar fashion to the above except that it was often necessary to discard part of an internode in order to have the basal cut just below a node. This however merely shortened the cutting but did not alter its relative position on the cane. In the first year the weakly vegetative canes were cut to make six cuttings each but only into four sections for chemical analyses. The cuttings were placed in their respective groups, tied into bundles, and stored inverted in a protected cold frame. In the early spring the glass was uncovered

TABLE I—RELATIVE VIGOR OF CANES AND NUMBER OF CUTTINGS MADE

Series	Ave. Length Cane (Inches)		No. Sections per Cane for Analyses		No. Cuttings per Cane Set in Field		Total No. Cuttings per Region Set in Field		Total No. Cuttings per Series	
	1929	1930	1929	1930	1929	1930	1929	1930	1929	1930
A	132.4	176.36	12	12	12	12	50	39	600	408
B	70.58	97.97	9	8	9	8	55	100	495	800
C	36.1	43.90	4 ¹	4	6	4	80	100	480	400

¹Cane cut into four pieces for chemical analysis but into six cuttings for field planting.

TABLE II—CHEMICAL COMPOSITION OF CONCORD GRAPE CANES OF DIFFERENT DEGREES OF VIGOR (EXPRESSED IN PERCENTAGE OF FRESH WEIGHT)

Date	Series	Degree of Vigor	Moisture (Per cent)	Free Reducing	Alc. Sol. Acid Hy-drolizable	Totals	Alc. Insol. Acid Hy-drolizable	Total Car-bohydrates	Soluble Nitrogen	Insoluble Nitrogen	Total Nitrogen
1929	A	Strong	40.89	2.38	2.44	4.81	13.06	17.89	0.019	0.39	0.41
	B	Moderate	42.41	2.88	1.48	4.36	11.82	16.18	0.018	0.40	0.42
	C	Weak	42.47	1.93	2.09	4.02	10.33	14.35	0.015	0.45	0.48
1930	A	Strong	42.77	1.75	1.28	3.03	13.58	16.61	0.021	0.30	0.32
	B	Moderate	42.67	2.41	1.25	3.66	13.91	17.57	0.028	0.32	0.35
	C	Weak	43.33	2.12	1.29	3.40	14.20	17.61	0.041	0.34	0.38



and all but about 2 inches of sand removed from the basal ends of the cuttings. In both years, root and shoot growth began practically at the same time. Shortly after the roots were visible the cuttings were examined individually for the amount of root and shoot growth. In the second year a record was also made of the amount of callus formed. Immediately after this examination the cuttings were set in the field to study the percentage of stand and the amount of top growth made.

As shown in Table I, the canes used the second year were considerably more vigorous than those used the first year. Table II shows that the canes of different vegetative vigor did not vary appreciably or consistently in the percentages of the various substances. Apparently the percentages of these substances in the cane as a whole are not materially changed by the degree of growth made by the cane. The less vigorous canes, that were produced in 1929, had higher percentages of total carbohydrates and total nitrogen than the more vigorous canes produced in 1930. When the canes of different vigor produced the same year were considered this uniform difference was found to exist only with the total nitrogen. It is possible that the much more vigorous canes for 1930 utilized more of their reserves in growth than did those for 1929 and thereby decreased the percentages. The differences in the amounts of growth made by the canes of different vigor the same year was not sufficiently great to materially alter the percentage of carbohydrate reserves but was sufficient to change the nitrogen reserves, for in all cases the most vigorous canes had the least nitrogen reserves.

The data in Table III, show that in general the terminal sections were lowest in the percentage of total carbohydrates, the basal regions were next, and the highest percentage occurred at some mid-point, being on the whole somewhat nearer the base than the tip of the cane. The total nitrogen did not show consistent differences in percentage. When the percentages were converted to the amounts of total carbohydrates and nitrogen per cutting or section (Table III) striking and regular differences were noticeable. This was due, of course, to the differences in the size of the cuttings.

In studying the growth of the cuttings at the time of removal from storage and before planting in the field it was found that for the 2 years the degree of initial rooting on all groups, with but one exception, was directly associated with the percentage of total carbohydrates. Those cuttings with the highest percentage of total carbohydrates produced the most roots in storage. The one exception was in series A of the first experiment which had the highest percentage of carbohydrates of the three series but had the least amount of initial rooting at the time of planting. There were no consistent differences in regard to the average amount of initial tops formed and the total carbohydrate reserves but there was an indication that the percentage of cuttings producing initial top growth was directly associated with the percentage of total carbohydrate reserves. Series A of the first experiment was again an exception.

The greatest amount of tops and roots and the highest percentage of cuttings forming roots and tops were shown to occur in those cut-

tings taken from the mid-portion of the strongly vegetative canes and on the cuttings taken from the basal half of the moderately and weakly vegetative canes. The cuttings from the less vigorous canes pro-

TABLE III—REGIONAL DISTRIBUTION OF TOTAL CARBOHYDRATES AND TOTAL PROTEINS IN PERCENTAGES AND AMOUNTS ON FRESH WEIGHT BASIS FOR 1931

Num- ber of Section	Total Carbohy- drates (Per cent)	Total Carbohy- drates per Cutting (Grams)	Total Nitrogen (Per cent)	Total Nitrogen per Cutting (Grams)
Series A				
1	16.37	5.96	0.37	0.14
2	17.98	6.54	0.29	0.11
3	17.92	6.74	0.28	0.11
4	17.88	5.79	0.35	0.11
5	17.23	4.69	0.33	0.09
6	17.43	4.53	0.27	0.07
7	16.59	3.95	0.30	0.07
8	16.51	3.76	0.33	0.08
9	16.34	3.00	0.31	0.06
10	15.46	2.47	0.33	0.05
11	15.01	1.80	0.35	0.04
12	14.65	1.37	0.34	0.03
Series B				
1	16.33	2.37	0.35	0.05
2	17.72	2.11	0.39	0.05
3	18.20	1.93	0.39	0.04
4	17.98	1.56	0.35	0.03
5	17.85	1.59	0.36	0.02
6	17.43	1.24	0.34	0.02
7	17.60	0.99	0.32	0.02
8	17.43	0.80	0.32	0.01
Series C				
1	17.83	1.23	0.38	0.03
2	18.21	1.12	0.36	0.02
3	18.16	0.70	0.36	0.01
4	16.22	0.45	0.41	0.01

duced the largest amount of roots and had the highest percentage of cuttings making such growth. There is an indication that the degree of initial rooting and the initiation of top growth in the cuttings, while still in the storage pit, were associated with the percentage of total carbohydrate reserves. The differences in the percentages of total carbohydrates alone, hardly seem sufficient to account for this difference in growth, but it does appear as if growth started soonest in those cuttings taken from the canes in the lower state of vegetative vigor.

Callusing seemed to be separate and distinct from rooting. These two processes seem to be independent collateral manifestations of internal conditions of the cutting.

The responses of the cuttings in the field were exactly the reverse of their responses of initial growth in the storage pit, since, for both years in the field, the cuttings from the more vigorous canes made the best top growth and had the highest percentage stand. Two things may have contributed to this difference namely, the partial depletion of food reserves by the early growth in the storage pit; and the difference in the amounts of food reserves in the different cuttings. More

TABLE IV—REGIONAL DISTRIBUTION OF AVERAGE AMOUNT AND PERCENTAGE OF GROWTH IN THE FIELD 1930 AND 1931

Growth	Series	Section of Cane Numbered from Base to Tip											
		1	2	3	4	5	6	7	8	9	10	11	12
		Top (1930)											
Amount of growth	A	28.52	22.40	20.62	32.00	30.40	30.62	23.62	11.37	3.20	7.90	0.0	0.0
	B	7.56	3.45	2.63	5.72	1.36	32.27	0.92	0.0	0.0	—	—	—
	C	7.26	1.89	4.0	0.0	0.0	—	—	—	—	—	—	—
Percentage growing	A	67.50	62.50	65.0	65.0	77.5	60.0	57.5	42.5	7.69	12.90	0.0	0.0
	B	41.81	23.63	14.54	27.27	9.09	14.54	5.55	0.0	0.0	—	—	—
	C	21.25	8.86	14.66	0.0	0.0	0.0	—	—	—	—	—	—
Top (1931)													
Amount of growth	A	22.8	21.2	18.3	16.25	21.0	22.74	23.28	23.85	21.87	34.78	24.82	27.00
	B	17.44	15.2	15.3	20.67	28.81	22.53	22.11	19.31	—	—	—	—
	C	17.6	13.0	4.1	5.7	—	—	—	—	—	—	—	—
Percentage growing	A	89.2	84.5	92.3	92.3	100.0	79.4	89.7	69.2	41.0	59.8	43.5	23.0
	B	63.0	56.0	49.0	52.0	59.0	71.0	52.0	22.0	—	—	—	—
	C	25.0	25.0	32.0	26.0	—	—	—	—	—	—	—	—

¹Field growth in 1930 from canes that grew in 1929, etc.

of the cuttings from the less vegetative canes were rooted than were those of the more vigorous cuttings and also their roots were farther advanced. The differences in tops were not so marked. In planting in the field this initial root and shoot growth was practically all destroyed so that the reserves of such cuttings were depleted to that extent. As shown in Table III, the cuttings from the more vigorous canes, being considerably larger, especially in diameter, had much more food reserves than the corresponding cuttings from the less vigorous canes so that they had a much better opportunity of establishing new root and top systems.

As noted previously the root and top growth made by the different sections of a cane seemed to be associated with the food reserves of the cutting. There was a decrease in the amount of growth from the base to the tip with the maximum usually occurring at some region between the base and middle of the cane. The responses in the field (Table IV) were more pronounced than those in the storage pit. In 1930, although there were fluctuations in the average amount of tops produced and in the percentage of stand and although these variations did not correspond exactly with the chemical reserves, there was a pronounced decrease of both from the basal to the terminal cuttings. In the strongly vegetative and moderately vegetative canes none of the cuttings from the last two sections survived the summer and all of the cuttings from the last three terminal sections of the weakly vegetative canes died.

The differences in 1931 do not appear so obvious in Table IV, but during the entire season they were very noticeable. All surviving cuttings taken from the strongly vegetative canes and the central region of the moderately vegetative canes were conspicuously more vigorous during the entire growing season. The basal and terminal cuttings appear to have done as well as those from the central portion of the canes but it will be noticed from the table that the percentage stand was not nearly so high. Those cuttings from these sections that lived made an amount of growth equal to that made by the cutting from the other sections of the vigorous canes. Cuttings from Series A, Sections 3 and 4 and small parts of Sections 2 and 5; Series B, Section 3 and part of Section 2, were growing in a less favorable soil situation for the difference in amount of top growth in this localized area of the plot was quite marked. Taken as a whole there was no noticeable difference in the amount of top growth made by the cuttings of Series A and B. The basal and terminal cuttings of Series B and the basal cuttings of Series A were the less vigorous. Cuttings in Series C were very weak throughout. The percentages of cuttings surviving in the field, especially in Series A and B seems to be associated with the amount of food reserves. The vigor of vines the first year was found to be directly associated with the vigor of the canes from which the cuttings were made. As a whole the cuttings, middle and basal regions of the cane, produced the most vigorous vines. The percentage of reserve carbohydrates and nitrogen did not differ appreciably in canes of different vegetative vigor. The amount of reserve carbohydrates and nitrogen differed markedly in the various section of a cane from the base to the tip, the largest amounts being near the basal end.

Further Studies on the Effect of Fruiting on the Shoot Growth of the Concord Grape

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IN 1931, studies were continued (1) to determine the effect of blossom and fruit removal before and after setting of the fruit on the shoot growth of the vine, measuring the influence in terms of shoot elongation during several periods in the growing season. The clusters were removed from individual shoots to compare with fruiting shoots on the same vines to measure again the individuality of the shoot which was evident to some degree in 1930. The same vines which had all the clusters removed before and after setting of the fruit in 1930 were subjected again to the same treatment to compare with fruiting vines in the same experiment. In 1930, considerable stimulation to shoot growth resulted on vines from which all clusters had been removed before setting of the fruit; however, but little stimulation resulted when the clusters were removed just after the setting of the fruit.

In addition to repeating the work of 1930, a larger number of vines were used to determine the effect of removing all clusters from vines before and after setting of the fruit as well as the effect of leaving one cluster per shoot, removing the other clusters before setting of the fruit.

RESULTS OBTAINED

In Table I are presented the data on individual shoots to determine the individuality of the shoot in competition with other shoots with various treatments on the same vine. Contrary to the results of 1930, the removal of clusters before setting did not stimulate the growth of shoots in comparison with the growth of fruiting shoots on the same vines. It is possible that the favorable growing conditions in 1931, in contrast to the dry conditions of 1930, served to offset the effects of fruiting. The stimulation of shoot growth when the clusters were removed after setting of the fruit, indicated in Table I, was also noted in 1930, which may mean that setting of the fruit did stimulate the growth of the shoot, as Murneek (2) found with the tomato. Comparing 1930 and 1931, it is apparent that the grape shoot may or may not have an individuality in growth response, depending upon the seasonal conditions. However, it must be noted that the average shoot growth of 1930 was only about 20 per cent less than that of 1931, as shown in Table I, because most of the growth in length is completed by July 15.

When the data in Table II is considered, in which the growth of vines is shown, following the removal of clusters before and after

TABLE I—EFFECT OF REMOVAL OF BLOSSOMS AND FRUIT CLUSTERS FROM INDIVIDUAL SHOOTS OF CONCORD GRAPE VINES BEFORE AND AFTER SETTING OF FRUIT

Treatment	No. Shoots	Average Length Shoot (Cms.) May 25	Average Increase in Shoot Growth (Cms.)					Total Increase
			May 25 to May 27	May 27 to May 29	May 29 to June 15	June 15 to July 15	July 15 to Oct. 28	
All clusters left May 25.....	32	52.9	4.9	8.2	75.7	86.7	32.4	207.9
All clusters removed May 25.....	32	48.7	4.5	6.9	69.9	94.5	34.0	209.8
One cluster left May 25.....	32	52.1	4.4	8.3	70.5	81.8	40.0	205.0
One cluster left June 15.....	32	49.3	4.3	7.4	74.1	93.2	33.6	212.6
All clusters removed June 15.....	32	49.1	4.5	7.7	76.4	105.4	50.2	244.2

Note: Cluster removal May 25 means before setting of the fruit, while cluster removal June 15 means after setting.

TABLE II—EFFECT OF BLOSSOM AND FRUIT REMOVAL ON THE SHOOT GROWTH OF CONCORD GRAPE VINES IN 1931.

Treatment	Vine No.	Number Shoots Measured	Ave. Length Shoot (Cms.) May 25	Average Increase in Length of Shoot (Cms.)				
				May 25 to May 29	May 29 to June 15	June 15 to July 15	July 15 to Oct. 28	Total Increase
All clusters removed in 1930 and 1931 (before setting of fruit, May 25, 1931.)	1	10	60.5	14.5	93.4	85.0	1.5	194.4
	5	10	52.1	9.1	75.1	128.1	42.2	254.5
	8	10	53.8	14.0	76.2	126.0	66.0	282.2
	11	10	48.0	11.3	71.1	100.0	47.6	230.0
	14	10	54.6	16.3	107.3	150.1	20.0	293.7
Average.....	—	—	53.8	13.0	84.6	117.8	35.5	251.0
All clusters removed in 1930 and 1931 (after setting of fruit, June 15, 1931.)	2	10	52.9	15.0	80.2	95.4	80.4	271.0
	6	10	40.2	11.2	71.2	92.2	47.3	221.9
	9	10	54.5	12.4	77.6	82.7	4.2	176.9
	12	10	54.7	14.9	89.5	139.5	62.7	306.6
	15	10	48.1	11.5	73.8	61.0	0.0	146.3
Average.....	—	—	51.3	13.0	78.5	94.2	38.9	224.5
All clusters left, 1930 and 1931.....	3	10	49.5	10.3	69.1	70.8	8.0	158.2
	7	10	59.3	11.9	67.0	84.8	18.3	182.0
	11	10	58.7	15.6	95.3	91.1	22.7	224.7
	13	10	51.3	12.9	84.0	75.5	63.7	236.1
	17	10	53.2	8.6	76.9	46.7	0.0	132.2
Average.....	—	—	54.0	11.9	78.5	73.8	22.5	186.6

setting in successive years of 1930 and 1931 on the same vines, there is a markedly greater shoot growth under both treatments, but removing the clusters before setting has stimulated growth more than the removal after setting. The removal of clusters from entire vines after setting in 1930 had little effect on the length of shoot growth in that season, but the repetition of the treatment on the same vines in 1931 had a marked effect compared with the growth response of fruiting vines. However, the growth response of these vines which have not borne any fruit in two seasons is not so great as might be expected, a fact which might be explained on the basis of root competition, the vines being planted 8 by 10 feet. On the other hand, no data is available as to the maximum average shoot growth which a Concord grape vine will make under a given condition. The average shoot growth of 304.8 centimeters attained by the vines which had the clusters removed before setting in both years may or may not be the maximum for this vineyard under the present soil, pruning, and cultural conditions. It can be noted in Table II that the amount of growth made after July 15 was greater in the case of the non-fruiting vines than on the fruiting vines, indicating that growth may have stopped earlier in the case of the latter.

In Table III, there is presented more data on the effect of cluster removal from entire vines. The experiments were conducted upon two types of vines, based upon the pruning weights, that is the amount of 1-year wood removed at pruning time prior to the experiment. The so-called weak vines were arbitrarily the vines with less than $2\frac{1}{2}$ pounds of prunings, and the strong vines thus had more than that amount of pruning. When clusters were removed before setting, the stimulation in growth of shoots was similar to that shown in Table II. The effect was relatively greater in the case of the weak vines than in the case of the strong ones, but both responses were marked and were noted early in the season, in contrast to the somewhat slower response in 1930. When the clusters were removed after setting, the growth stimulation was not so great as that which resulted from the removal of clusters before setting. The removal of all clusters but one per shoot before setting apparently stimulated the shoot growth of the weak vines to about the same degree as the removal of all clusters after setting, but leaving one cluster per shoot on strong vines resulted in no stimulation. Apparently, blossom thinning may increase the vegetative vigor of weak vines but not necessarily the vigor of strong vines.

CONCLUSIONS

The removal of blossom or fruit clusters from Concord grape vines early in the growing season has a definite stimulative effect on shoot growth which is greater if done before setting of the fruit. The devitalizing effect of fruiting on the vegetative growth of the vine has usually been considered greater than this response of the vines after removal of the inflorescence or young fruits inversely

TABLE III—EFFECT OF BLOSSOM AND FRUIT REMOVAL ON THE SHOOT GROWTH OF CONCORD GRAPE VINES

Treatment	Number of Vines	Average Length Shoot Growth May 25	Average Increase in Shoot Growth (Cms.)					Total Increase
			May 25 to May 29	May 29 to June 16	June 16 to July 15	July 15 to Oct. 28		
"Strong" Vines								
All clusters left.....	8	54.2	12.1	76.9	56.9	8.0	153.9	
All clusters removed before set (May 25).....	8	54.4	12.8	82.3	108.0	26.7	229.8	
All clusters removed after set (June 16).....	8	56.2	11.6	75.5	94.4	24.0	205.5	
One cluster left per shoot before set.....	7	51.7	10.1	69.9	56.4	6.5	142.9	
"Weak" Vines								
All clusters left.....	5	53.0	9.7	61.3	20.2	1.9	93.1	
All clusters removed before set (May 25).....	4	48.5	10.9	79.2	105.9	9.9	205.9	
All clusters removed after set (June 16).....	3	50.6	10.6	58.0	68.4	17.5	154.5	
One cluster left per shoot before set.....	4	51.8	8.9	68.2	66.1	12.9	156.1	

Note: Ten shoots were measured on each vine.

would indicate. Improving the vegetative vigor of Concord grape vines by blossom thinning may depend upon the vegetative condition of the vine at the moment or possibly the root competition among vines under soil and climatic conditions in the eastern states.

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Effects of Pruning on Fruiting of Shoots and the Growth of Their Terminals and Laterals in the Concord

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L. R. TUCKER, *University of Idaho, Moscow, Ida.*

ABSTRACT

The complete paper will appear as a bulletin from the Illinois Agricultural Experiment Station.

IN a study of the cumulative effects of five consecutive years' (1924-28 inclusive) consistent winter pruning of the Concord grape at Urbana, Illinois, to varying degrees of severity, certain conclusions were drawn as to the fruiting of shoots and the growth of their terminals and laterals. Data were secured from 48 vines ranging from the 20-29 node to the 80-89 node group in 1927, and from 64 vines which ranged up to the 60-69 node group in 1928. Approximately 2000 shoots were studied each year.

The total amount of shoot length produced was little affected by the severity of the previous winter's pruning. The vigor of individual shoots was, however, increased proportionately. Increasing vigor of weak shoots was most evidenced by increased length, and of very vigorous shoots by the growth of laterals.

The total yield was greatly influenced by the severity of the previous winter's pruning through limiting the possible number of fruit clusters. As fewer buds were left at pruning time and the number of potential shoots reduced, the number of clusters resulting was automatically lessened. The yield of individual shoots from the buds left to grow was not noticeably changed.

Except under very unusual conditions during the fruiting season, the ability of a shoot to yield was largely determined in the bud the previous year, while shoot vigor was markedly affected by the number of nodes left on the vine at pruning time.

In attempting to balance growth and yield of the Concord at pruning time, the growth of last season's shoot may be used as an index of vigor and productivity. Concord vines pruned to 56-65 nodes under the conditions of the experiment bore shoots that were moderately vigorous but not vigorous enough to produce much, if any, lateral growth. Vines with such a type of growth carried through large bunches to full maturity each year, and at the same time matured a sufficient number of medium size, well-placed shoots from which a good choice of fruiting canes could be made at pruning time.

The Influence of Long Pruning and Thinning upon the Quality of Concord Grapes

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PREVIOUS data (1) indicated that the juice from Campbell Early grapes produced by severely pruned vines contained a higher percentage of total solids than did the fruit on lightly pruned vines. Additional data obtained from Concord grape vines are presented here.

A number of vines of approximately equal vigor were selected in the vineyard at the Graham Horticultural Experiment Station at Grand Rapids and were given "longer" pruning than usual. Between 80 and 90 nodes were left on these vines instead of the 42 to 50 nodes usually retained. The vines were divided into four groups, three of which were thinned. The thinning was done (1) by rubbing off alternate buds at the time growth started in the spring, (2) by removing any blossom clusters in excess of two per shoot, and (3) by removing all clusters in excess of one per shoot. Those blossom clusters retained were the largest on the shoot, usually the basal one or two. The test was repeated the following season using different individuals. For purposes of comparison, growth and yield data are included from similar vines pruned in the usual manner. The data are presented in Table I.

The thinning reduced the amount of fruit produced. Blossom thinning to one cluster per shoot or the removal of alternate buds at the beginning of growth reduced the production to about that of normally pruned vines. Blossom thinning to two clusters per shoot did not reduce the yield very much, particularly the first season. Samples of grapes were obtained from each vine and the percentage of total solids was determined by the Brix hydrometer. These data show that the juice from the fruit on the thinned vines contained a higher percentage of total solids than did the fruit from the unthinned or slightly thinned long-pruned vines. As in the Campbell Early, the smaller the production, the greater the percentage of total solids indicated. This was observed in 1927, when the yield was small, as well as in 1928 when the production was greater.

Blossom thinning apparently tended to increase the weight of the bunches. The greater weight of the bunches on the vines that were thinned to one cluster per shoot at blooming time was due, to a considerable extent, to the selection of the smaller clusters for removal. However, the fruit harvested from the vines thinned to a single cluster per shoot was of better appearance and flavor than the fruit from the unthinned long-pruned vines, and the clusters were heavier

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than those produced on vines thinned by the removal of alternate buds or by vines normally pruned.

TABLE I.—PRODUCTION OF CONCORD GRAPEVINES, THINNED BY DIVERSE METHODS

	Thinning Treatment				
	Alternate Buds Removed	Thinned to One Blossom Cluster per Shoot	Thinned to Two Blossom Clusters per Shoot	Not Thinned	Normal Pruning
Crop of 1927					
Number vines.....	9	13	13	12	14
Average pounds prunings, 1926-27.....	3.1	3.0	3.0	3.0	3.0
Average pounds fruit, 1927.....	12.5	14.6	20.8	21.2	13.0
Average ounces per bunch.....	2.5	3.0	2.8	2.9	—
Average degrees Brix of juice.....	17.1	17.1	16.3	16.0	—
Average pounds prunings, 1927-28.....	4.0	4.5	4.5	4.7	3.9
Crop of 1928					
Number vines.....	12	12	12	12	12
Average pounds prunings, 1927-28.....	3.0	3.0	3.0	3.0	3.0
Average pounds fruit, 1928.....	19.7	19.0	31.3	36.1	21.1
Average ounces per bunch.....	3.2	3.9	3.4	3.0	—
Average degrees Brix of juice.....	15.5	15.5	14.3	14.5	—
Average pounds prunings, 1928-29.....	5.4	5.8	4.9	4.8	4.9

The production of fruit tends to reduce the amount of growth made by the vines (1, 2). However, Winkler (4) has shown that longer pruning tends to increase the amount of growth made by Vinifera varieties. These data, particularly those for the crop of 1928, indicate a similar tendency; but the increase in vigor due to long pruning, even with the removal of the excess blossom clusters, has not been very marked.

From the viewpoint of the grower, long pruning with the removal of the excess blossom clusters will result in the production of larger bunches of better appearance than when the crop is regulated entirely by dormant pruning. A slight increase of vine vigor will probably occur. There seems to be little difference in the time of fruit maturity when the production is equal under the two systems of management. On the other hand, there is a considerable increase in the amount of labor required for pruning and tying the vines. Extra labor is also required for thinning the blossom clusters at a time when the regular vineyard operations demand attention. Under present conditions of marketing, there is no probability of securing more than a moderate premium for the better quality of fruit that would be secured by the more laborious method of production. Consequently long pruning with cluster thinning does not seem to offer

the Concord grape grower any prospect of increased profit at the present time.

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The Effect of Fruit Production and Fertilizer Treatments on the Maturity of Concord Grapes¹

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DURING the course of an experiment on the influence of fertilizers on the production of Concord grapes (1), juice samples were obtained from many of the vines in the vineyard. Each lot of juice was extracted from a representative sample of the fruit from a single vine, the berries being pulped and squeezed through doubled muslin. Although this method was not so satisfactory as a careful chemical analysis would have been, the data are considered reasonably trustworthy, owing to the large number of tests made each season.

In another paper by the author published elsewhere in this report, it has been shown that vines producing an overcrop do not mature their fruit so well as do vines with smaller crops. Before sound conclusions could be reached regarding any direct influence of the several fertilizer treatments on the maturity of the fruit, it was necessary to determine whether the variations in vigor and productivity of the various vines were responsible for the differences that appeared. Data are presented in Table I giving the average percentage of total solids indicated by the Brix hydrometer for vines of different vigor (as measured by the weight of prunings removed the preceding winter) and production. The vines were all pruned in accordance with their vigor as has been described (1).

The data for both years show that the percentage of total solids in the juice tended to be lower as the production of the vine was greater. This relationship was apparent whether the population was considered as a whole or whether a subdivision was made, based on the weight of prunings the preceding winter. No definite relationship was observed when a comparison was made between the data obtained from vines of equal production but of varied vigor. Differences in the values of the averages of the various groups with equal production showed a slight tendency for the stronger vines to yield a juice with a greater percentage of total solids than the weaker vines, but no consistent trend appeared. When the data from all growth classes were averaged together regardless of the amount of their production, the weakest vines seemed to produce the fruit with the largest percentage of total solids. This was due apparently to the fact that the production of the weaker vines tended to be less in total weight than that of the stronger ones, and hence the average was higher.

In making comparisons between the vines receiving the different fertilizer treatments the data have been subdivided so that groups of vines of approximately equal production may be compared. These data are presented in Table II. No consistent differences in percent-

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TABLE I—THE INFLUENCE OF VARIATIONS IN THE VIGOR AND PRODUCTION OF VINES ON THE PERCENTAGE OF TOTAL SOLIDS IN THE EXTRACTED JUICE, EXPRESSED AS DEGREES, BRIX

Pounds of Fruit Harvested, 1926									
Pounds Prunings 1926-26	0.1-5.0 °Brix	5.1-10.0 °Brix	10.1-15.0 °Brix	15.1-20.0 °Brix	20.1-25.0 °Brix	25.1-30.0 °Brix	30.1-35.0 °Brix	35.1-40.0 °Brix	40.1-45.0 °Brix
0.1-1.0	15.9 (13)*	15.7 (21)	15.3 (21)	15.4 (3)	15.4 (5)	—	—	—	15.6 (58)
1.1-2.0	16.1 (1)	15.8 (54)	15.5 (54)	15.3 (35)	14.9 (26)	14.7 (5)	—	—	15.5 (104)
2.1-3.0	—	15.7 (5)	15.7 (23)	15.4 (49)	15.2 (24)	14.9 (6)	—	—	15.3 (108)
3.1-4.0	—	15.8 (1)	15.4 (7)	15.2 (13)	15.2 (11)	15.1 (1)	—	—	15.2 (51)
4.1-5.0	—	16.0 (1)	15.2 (1)	15.5 (5)	—	—	—	—	15.3 (23)
5.1-6.0	—	14.9 (1)	—	—	—	—	—	—	14.9 (1)
0.1-6.0	16.0 (14)	15.7 (43)	15.5 (106)	15.3 (105)	15.1 (66)	14.9 (16)	—	—	15.4 (350)
Pounds of Fruit Harvested, 1927									
Pounds Prunings 1926-27	0.1-5.0 °Brix	5.1-10.0 °Brix	10.1-15.0 °Brix	15.1-20.0 °Brix	20.1-25.0 °Brix	25.1-30.0 °Brix	30.1-35.0 °Brix	35.1-40.0 °Brix	40.1-45.0 °Brix
0.1-1.0	17.4 (18)	17.0 (62)	16.7 (45)	15.9 (9)	16.0 (2)	15.7 (2)	—	—	16.8 (138)
1.1-2.0	17.0 (3)	16.9 (36)	16.9 (110)	16.3 (86)	16.0 (17)	17.8 (2)	16.4 (1)	—	16.6 (255)
2.1-3.0	18.2 (1)	17.3 (5)	16.6 (26)	16.4 (75)	15.7 (52)	14.9 (8)	14.4 (1)	—	16.1 (168)
3.1-4.0	—	17.4 (1)	17.0 (7)	16.3 (22)	16.0 (24)	16.0 (14)	—	14.3 (1)	16.2 (69)
4.1-5.0	—	—	18.0 (1)	16.0 (2)	16.5 (2)	15.9 (6)	15.3 (2)	—	16.1 (13)
5.1-6.0	—	—	—	—	—	—	16.4 (2)	—	1.64 (2)
0.1-6.0	17.4 (22)	17.0 (104)	16.8 (189)	16.3 (194)	16.0 (97)	15.8 (32)	15.7 (6)	14.3 (1)	16.5 (645)

*Numbers in parentheses indicate number of individual vine samples included in calculating mean.

TABLE II—THE INFLUENCE OF FERTILIZER TREATMENTS UPON THE PERCENTAGE OF TOTAL SOLIDS IN THE EXTRACTED JUICE, EXPRESSED AS DEGREES, BRIX

Pounds Fruit Harvested	Fertilizer Applications					Nitrate phosphate potash
	None	Nitrate alone	Ammonium sulphate	Ammonium sulphate lime	Nitrate phosphate	
	Crop of 1926					
0.1-5.0	°Brix 15.9 (9)*	°Brix 16.1 (3)	°Brix —	°Brix —	°Brix 15.6 (1)	°Brix 15.6 (4)
5.1-10.0	15.8 (19)	15.6 (9)	—	—	15.7 (9)	15.6 (18)
10.1-15.0	15.4 (27)	15.5 (17)	—	—	15.5 (18)	15.3 (28)
15.1-20.0	15.4 (4)	15.4 (22)	—	—	15.4 (25)	15.3 (16)
20.1-25.0	15.0 (6)	14.8 (26)	—	—	15.1 (10)	15.2 (6)
25.1-30.0	—	14.8 (3)	—	—	14.4 (6)	—
0.1-30.0	15.6 (65)	15.3 (74)	—	—	15.3 (68)	15.4 (72)
	Crop of 1927					
0.1-5.0	°Brix 18.3 (9)	°Brix 16.0 (3)	°Brix 16.7 (2)	°Brix 16.7 (3)	°Brix 17.7 (1)	°Brix 16.6 (1)
5.1-10.0	17.7 (32)	16.7 (16)	17.0 (3)	16.0 (15)	16.1 (9)	16.8 (4)
10.1-15.0	17.2 (41)	16.7 (24)	16.6 (19)	16.5 (19)	16.6 (20)	16.8 (22)
15.1-20.0	16.6 (26)	16.2 (48)	16.3 (17)	15.7 (15)	16.1 (22)	16.5 (32)
20.1-25.0	16.0 (9)	16.0 (26)	16.0 (9)	15.5 (8)	15.7 (19)	15.7 (14)
25.1-30.0	15.8 (4)	15.4 (8)	15.9 (5)	16.4 (1)	16.9 (3)	15.7 (5)
30.1-35.0	—	—	—	—	—	—
0.1-35.0	17.2 (121)	16.2 (125)	16.3 (55)	16.0 (61)	16.2 (74)	16.4 (78)

*Numbers in parentheses indicate number of individual vine samples included in calculating mean.

age of total solids appeared in the data for 1926 that would suggest any influence of fertilizer treatment on the percentage of total solids. When all the vines studied on each of the plots were grouped together, the unfertilized vines showed a higher average, apparently because these vines were less productive.

When comparisons were made between vines of approximately equal production, the data for 1927 showed that the averaged readings of juice from the unfertilized vines were consistently higher in total solids than those from any of the plots receiving nitrogen, either alone or in combination. The one exception was found in the case of vines yielding from 25.1 to 30.0 pounds of fruit. It is more difficult to draw definite conclusions as to the relationship between the fertilizer treatment and the percentage of total solids when the influence of the other elements is considered. When lime was added to the nitrogen the percentage of total solids apparently was lessened somewhat.

When phosphorus was added to the nitrogen, it apparently had comparatively little influence on the percentage of total solids. Although two groups with but few individuals showed considerably higher averages than do vines of similar production on plots receiving nitrogen without lime, the groups with the larger numbers of vines showed somewhat lower averages. The addition of potash to nitrogen appeared to cause an increase in the percentage of total solids, although this increase was not enough to permit these groups to equal the unfertilized groups. The addition of phosphorus and potash to nitrogen tended to produce higher averages than those obtained from the vines receiving phosphorus and nitrogen. Where the differences between the averages of the nitrate-potash and the nitrate-phosphate-potash plots were larger, the nitrate-potash plot usually shows the larger values, the reverse being true where the differences were smaller.

These data are not conclusive of the advantage of any fertilizer treatment in increasing the percentage of total solids or hastening maturity. However, the number of individual tests is large enough so that these results may be considered to be more or less typical of the kind and the amount of variations to be encountered in this vineyard with carefully balanced pruning of the vines. There is some indication that the use of nitrogen delays the maturity of grapes, which seems to be the general experience of grapegrowers in Michigan who have used it. There is also a suggestion that the use of potash with nitrogen may tend to reduce the delay induced by the use of nitrogen some seasons, but further data must be obtained before this conclusion can be established.

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Irrigation Experiments With Grapes

By A. H. HENDRICKSON and F. J. VEIHMAYER, *University of California, Davis, Calif.*

IRRIGATION experiments similar to those with peaches, reported at a previous meeting of this society (1), were conducted with two varieties of grapes in the San Joaquin Valley of California in 1930 and 1931. These experiments were carried on with the Thompson Seedless (Sultanina), a table and raisin variety, near Hughson and with the Emperor, a table variety, near Sanger.

EXPERIMENTS WITH THOMPSON SEEDLESS

The experiments with the Thompson Seedless variety were carried out at Hughson on a Fresno sandy loam soil. The moisture equivalents¹ of the soils in the experimental plots vary from about 9 to 11 per cent in the top 5 feet, and the permanent wilting percentages (2) vary from about 3 to 4 per cent. In these soils, the field capacity is a little higher than the moisture equivalent (3).

Soil samples in 1-foot increments were taken at weekly or bi-weekly intervals in sufficient numbers to give a reliable soil-moisture record of the plots. Frequent, systematic soil sampling, together with a knowledge of the permanent wilting percentages of the soils used made it possible to vary the soil moisture between the field capacity and the permanent wilting percentage, without actually reaching the latter condition unless it was so desired.

The plots contained 30 vines each with double guard rows between plots. The only variation in the cultural treatment of the plots was in the number of times they were irrigated. Three plots were used in 1930 and five plots in 1931. Only the records from the plots used both years are given in this paper. The soil samples were dried for 48 hours at 105 to 110 degrees C., and the moisture contents calculated on the dry-weight of soil. Three irrigation treatments were used.

The soil-moisture records for 1930 and 1931 are essentially similar and only those for 1931 are given in this paper (Fig. 1). Most of the roots were probably in the upper 5 feet, because of an impervious layer at about this depth. The records for treatment C prior to July 7 are omitted since they are practically the same as those of treatment A. The soil moisture in treatment A was kept well above the permanent wilting percentage in the first 5 feet of soil, except for a brief period in the first foot early in the season of 1931. This treatment received five irrigations. The presence of a compact layer just below the depth of cultivation, known as plow-sole, interfered with

¹The terms, relating to soil moisture, used in this paper, and their relation to one another, are discussed in California Agric. Ext. Service Cir. 50.

the downward movement of water, and accounts for the high moisture contents in the top foot following irrigations. Treatment B received one irrigation, and the soil-moisture was reduced to the permanent wilting percentage in the top 3 feet and remained there until irrigated on June 17. It was again reduced to the permanent wilting

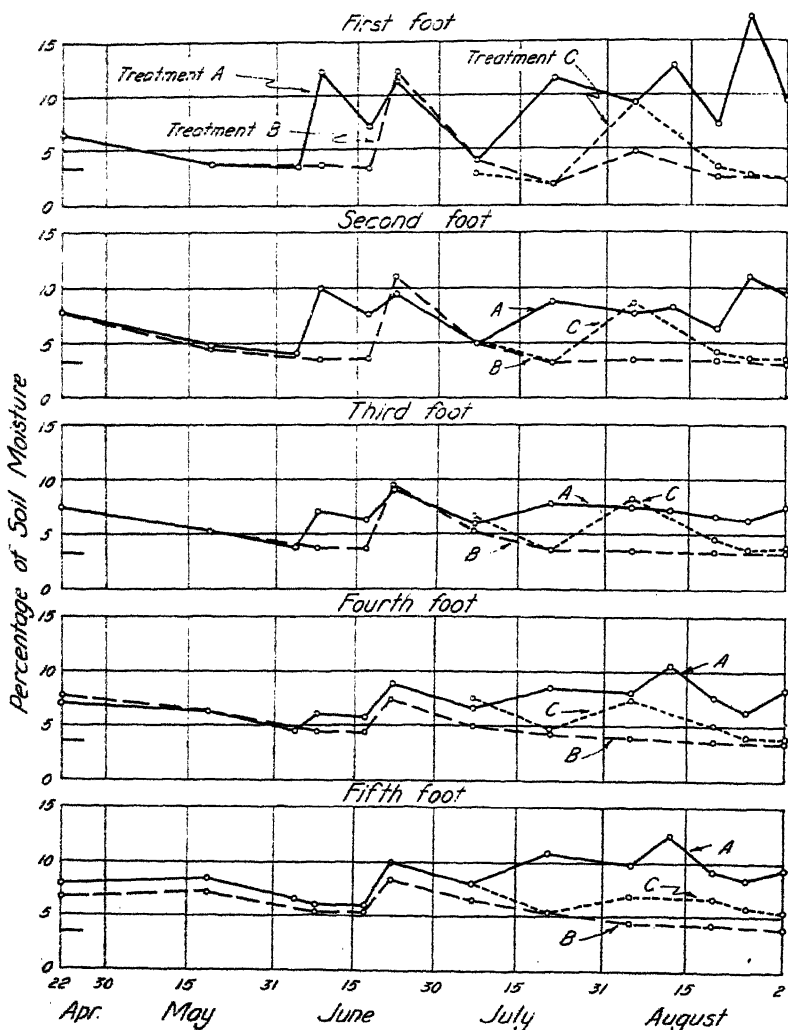


FIG. 1. Soil-moisture conditions in the Thompson vineyard, Hughson, California, 1931. The increase in soil-moisture on September 2, in the third, fourth, and fifth feet in treatment A, is due to plow sole. The water was applied on August 22, but did not have time to penetrate beyond the second foot by August 26, when the samples were taken. The permanent wilting percentages are indicated by the short lines at the left of the diagram.

percentage about July 21, when the vines wilted. The flattened portion of the dashed line indicates that practically no soil-moisture was removed from the second and third feet after July 21, and but very little from the fourth and fifth. The peak in the B treatment line in the first foot on August 5 is due to the accidental wetting of a portion

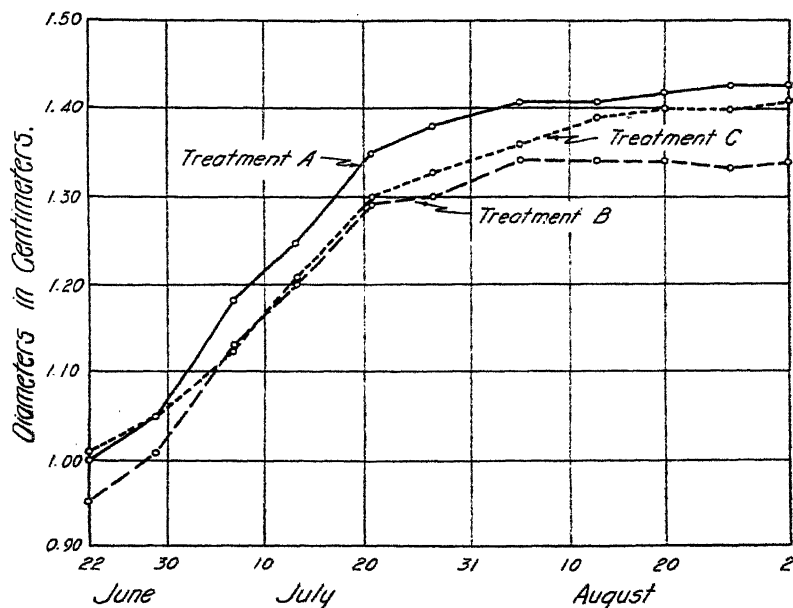


FIG. 2. Growth of Thompson grapes at Hughson, California, 1931.

of the plot but, as the water only penetrated a few inches, no response was observed either in the vines or fruit. The last irrigation was applied to treatment C during the first part of August, and its soil-moisture content was reduced, in the upper 4 feet to the permanent wilting percentage on August 26, about 1 week before harvest.

Growth of the fruit was measured the first year by weighing and counting a large number of berries secured at random. This method did not yield consistent results, because of the variation in the size of the berries both from different bunches and from different places on the same bunch. In 1931 the diameters of marked berries were measured by means of a specially designed precision caliper, which could be read to 0.01 centimeters. Five berries on each of 20 bunches were measured during the last half of the season. By measuring the same berries each week a consistent curve was obtained. The growth curve of the Thompson Seedless grapes in 1931 is given in Fig. 2. The differences in size of the grapes in all three plots were on the border line of significance until July 21. Thereafter, the diameters of the berries in treatment B were significantly smaller than those in

treatment A. It should be noticed that the soil-moisture in the upper 3 feet in treatment B was reduced to the permanent wilting percentage at this time. The diameters of the fruit in treatment C were significantly larger than those in treatment B when the crop was picked. The small size of the berries in treatment B when the measurements

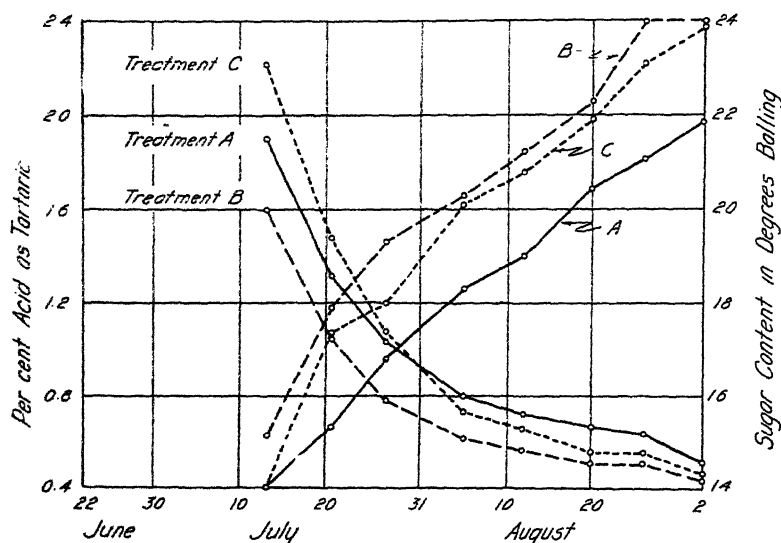


FIG. 3. Acid and sugar contents of Thompson grapes at Hughson, California, 1931.

were started may be explained by the fact that the soil-moisture in this treatment was at the permanent wilting percentage from June 8 to June 17. Lack of readily available soil moisture, however, cannot be the reason for the slow rate of growth of the fruit in treatment C between June 22 and July 7, because the soil-moisture content in this treatment was essentially the same as that in treatment A.

Determinations of the sugar by hydrometer readings on expressed juice, and acid contents of the berries by titration were made during the latter part of the growing season. The results obtained in 1931 are shown in Fig. 3. In general it will be seen that the rate of increase in sugar was essentially the same in all treatments. The sugar in treatment A, on July 13, was one degree Balling lower than treatment B and this difference became gradually larger until on September 2 when the grapes were picked there was a little over 2 degrees difference between these treatments. On June 17 the new length growth on the vines in treatment B was distinctly less than in treatment A, which was due to the fact that the soil-moisture in the B treatment was reduced to the permanent wilting percentage between June 8 and 17. The heavy growth of vines and foliage in treatment A, therefore, may have been a factor in retarding the ripening of the fruit in

this treatment. In other words, the fruit from treatment A may have been picked before it was fully mature. In 1930, however, when the crop was picked about a week later than in 1931, the degree of maturity of the fruit from both treatment A and treatment B was the same. This is shown in Table I which gives the sugar and acid contents, sizes and drying ratios at harvest for both years of the experiment. In spite of the similarity of soil-moisture conditions in treatments A and C in 1931, except during the last three weeks of the season, the sugar contents of the fruit in treatment C showed as great departures from those of A as did the sugar contents of the fruit of treatment B. The authors can offer no explanation for this behavior.

TABLE I—SUGAR AND ACID CONTENTS, DRYING RATIOS, AND SIZE OF THOMPSON (SULTANINA) GRAPES WHEN PICKED

Treatment	Year	Balling (Degrees)	Acid as Tartaric (Per cent)	Drying Ratio	Size of Berries (Cms.)	Average Weight of Berries (Grams)
A	1930	22.4	0.53	3.9	—	1.73
B	1930	22.4	0.45	3.9	—	1.85
C	1930	22.0	0.47	3.9	—	1.85
A	1931	21.9	0.51	4.1	1.43±.005	—
B	1931	23.9	0.42	3.7	1.34±.005	—
C	1931	24.1	0.44	3.7	1.41±.006	—

The ratios between the weight of fresh fruit and the weight of raisins were obtained both years by drying approximately 12 kilograms of fruit from each treatment in a small dehydrater in which the temperatures were controlled within close limits. The data show that the Thompson fruit from all treatments in 1930 was of essentially the same degree of maturity when harvested, and no differences were obtained in the drying ratios. In 1931, however, there were differences in the sugar contents, and these differences were reflected in the drying ratios.

Three pickings of fruit at weekly intervals were used in storage tests. These pickings were divided into four lots as follows: (1) held at 32 degrees F., (2) held at 50 degrees F., (3) held at 32 degrees F. for 2 weeks after which it was held at room temperature, and (4) held at 50 degrees F. for 2 weeks and then kept at room temperature. The fruit held continuously at 32 degrees and 50 degrees F. for approximately 2 months showed no differences in keeping quality. Of the fruit first held in cold storage and then exposed to room temperatures, that from treatment A kept, on the average, from 1 to 3 days longer than that from the other two treatments. In other words, the keeping qualities of the grapes, like those of peaches (4), were not materially affected by high soil-moisture contents during the ripening period.

EXPERIMENTS WITH EMPERORS

Experiments were also carried on in 1931 with Emperor grapes near Sanger on a San Joaquin loam soil, having a hardpan layer at about 6 feet. The moisture equivalents of the top 5 feet of soil vary from about 5.5 to 10.5 per cent, and the permanent wilting percentages from about 3 to 5 per cent. The general procedure followed in the experiments was the same as with the Thompsons. The fruit was picked November 3, or about 2 months later than the Thompsons.

TABLE II—SUGAR AND ACID CONTENTS, AND SIZE OF EMPEROR GRAPES, NOVEMBER 3, 1931

Treatment	Balling (Degrees)	Acid as Tartaric (Per cent)	Size of Berries (Cms.)	Average Weight of Berries (Grams)
A.....	20.2	0.47	1.87±.007	4.21
B.....	19.5	0.45	1.88±.007	4.28
C.....	20.7	0.48	1.89±.008	4.20

The soil moisture did not reach the permanent wilting percentage in any of the treatments, but in treatment B which received its last irrigation on August 3, it was close to this soil-moisture condition toward the end of the season. The soil-moisture in treatment A was well above the permanent wilting percentage throughout the season and, in fact, was above the moisture equivalent for a considerable portion of the time. This high moisture content was the result of frequent irrigations, and a lack of adequate drainage due to the presence of the hardpan layer. There was a marked difference in the amount of readily available soil-moisture in treatments A and B, especially during September and October. The omission of one irrigation late in the season allowed the soil-moisture in treatment C to more nearly approach the permanent wilting percentage than it did in A. Treatment A received nine; treatment B, two; and treatment C, six irrigations.

The growth measurements of the Emperor variety, which normally ripens about 2 months later than the Thompson, showed that the berries in all treatments did not increase in size after the first week in September. The acid content, likewise, remained practically constant after this date. The sugar content, however, continued to increase until the fruit was picked. The curves showing the changes in size, sugar, and acid content were substantially the same for all treatments.

No drying tests were made with this variety as it is essentially a table grape, but storage tests similar to those with Thompson were conducted. No evidence of differences in the keeping qualities of the fruit from the various treatments could be detected. The data for Emperor are given in Table II, from which it is evident that no significant differences were obtained in the values from the different treatments. The vines in this experiment did not wilt as they did in

treatment B with the Thompson. All treatments had readily available soil-moisture throughout the season, and no differences were obtained in the growth or quality of the fruit, even though there was a marked difference in the amounts of readily available soil moisture.

CONCLUSIONS

The general conclusions that may be drawn from results obtained thus far are that the growth and fruiting of grape vines, like those of peach trees (4), proceed in a normal manner if a supply of readily available moisture is maintained in the soil throughout the season. The moisture may fluctuate between the field capacity and the permanent wilting percentage, with no responses unless it is depleted to the latter condition and remains there for a considerable period. It was surprising that the results obtained with the Thompson did not show any greater differences than they did, because the B treatments were subjected to severe soil-moisture conditions.

Individual fruits of the Thompson and Emperor varieties reached approximately full size several weeks before they were fully mature as measured by color and by sugar and acid content. The size of the fruit was not influenced by water applied to the soil late in the season. Changes in maturity of both Thompson and Emperor proceeded regularly late in the season even when there was a marked difference in the soil-moisture contents of the various treatments. The keeping quality of the grapes from the treatments, irrigated more frequently than necessary, was fully as good as that from the treatments in which the final application of water was made $2\frac{1}{2}$ or 3 months before the crop was picked. No deleterious results were obtained when the vines were irrigated frequently during the latter part of the ripening period.

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Anatomical Differences in Pecan Varieties that Fruit Differently

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CERTAIN varieties of pecan trees in the Yuma Valley of Arizona produce some unfilled nuts popularly termed "sticktights." Such nuts at harvest time contain a seed coat comparable to that in well-filled nuts but in which little or no food materials have been stored. Food materials, if present, are to be found in the region near which the hypocotyl ordinarily lies. The shell does not mature at harvest time; likewise, the shuck remains green and adheres tightly to the shell. Sticktights are commonly borne on trees of the Kincaid variety, less so on those of Halbert. They are produced only to a limited extent on trees of Burkett, Success, Schley, Clark, and other varieties.

The production of sticktights has generally been thought by growers and others to be related to defective pollination. Some circumstances, however, have suggested that factors other than pollination may also be important. An investigation of the matter of filling was begun in September 1931. Some preliminary data have been obtained to date.

That growth character and leaf size may be related to some phases of fruiting in the pecan has been suggested (1). It was observed early in the present study that trees of the Kincaid and Halbert varieties bear rather small leaves and that they have many short and slender shoots with short internodes and small lateral buds. Kincaid appears also to produce a number of long shoots tapering from base to tip. These latter often do not blossom concurrently with their growth but appear to give rise the next season to several weak fruiting shoots. By comparison, Schley and Burkett trees have larger leaves. They produce a greater proportion of moderately long and uniformly thick shoots which have larger lateral buds. Fruiting shoots arise almost entirely from the more distal buds of the previous year's growth.

These observations seemed to indicate that the failure of the nuts to fill might be related to the kind or amount of growth produced. Five hundred to 1,000 nuts were collected a few days prior to harvest from strong and from weak fruiting shoots (1) of Kincaid, Halbert, and Burkett trees all growing in the same grove. These gave the data presented in Table I.

These data seemed to suggest that for Kincaid and Halbert at least there might be some relation between growth character and the production of sticktights. It seems equally evident from these data and from many observations that growth character and the accompanying leaf area alone are not completely correlated with filling. The number of nuts per shoot seems to enter in. A strong shoot bearing many nuts was observed to commonly have one or two sticktights. On

weak shoots having an equal number of nuts a larger proportion of sticktights was generally apparent. Nuts borne singly on strong shoots were observed to be well-filled generally, whereas single nuts on weak shoots were often sticktights.

TABLE I—PER CENT STICKTIGHTS OF TOTAL NUTS SAMPLED, YUMA VALLEY, ARIZONA, 1931

	Kincaid ¹	Halbert ¹	Burkett
Weak shoots.	36.9	32.4	5.9
Strong shoots.	25.6	17.1	6.8

¹These trees according to the owner's record produced up to 140 pounds of marketable nuts for each Kincaid and 175 pounds for each Halbert tree.

Studies of anatomical structures in shoots of different varieties were made as one means of obtaining an index of nutritional conditions within trees of the different varieties.

Strong fruiting shoots carefully selected for type (1) were collected from trees of different varieties on September 9, October 10, and October 28, 1931, and stored in formalin-alcohol-acetic acid solution. This procedure did not give exactly comparable shoots. The "strongest" shoots obtainable of Kincaid, particularly, and of Halbert to a lesser extent were not so uniformly thick from base to tip nor did they have such long terminal internodes as those from Burkett and Schley.

Freehand transverse sections were made at the tip and base of the shoots. These were stained with iodine in potassium iodide and mounted in a glycerine solution of the same. Data for ratio of xylem parenchyma to xylem fibers were obtained by counting cells in 10 to 15 representative fields of the last formed or outer xylem.

TABLE II—RATIO OF XYLEM PARENCHYMA TO FIBERS IN OUTER XYLEM OF STRONG SHOOTS

	Kincaid	Halbert	Burkett	Schley
Tip of shoot. ....	.22	.50	.69	.66
Base of shoot. ....	.28	.39	.38	.44

These preliminary data indicate differences in the proportion of parenchyma to fibers in the outer xylem of shoots of similar type in the different varieties. However, more complete data must be obtained before this point can be definitely proposed.

It is of interest that the varieties observed to have a high parenchyma to fiber ratio in the xylem are the ones which commonly have a low proportion of sticktights. (Data obtained on percentage of sticktights in different varieties this year gave Kincaid 31.2, Halbert 25.1, Burkett 7.1, and Schley 9.7.) It has been previously reported (2) for the apple that the accumulation in the shoot of an abundance of carbohydrates during the summer is accompanied by the formation of many parenchymatous cells in the xylem.

The "strong" shoots of the different varieties collected in October were found to be unlike in starch content as observed in the sections for anatomical study. At the tip of the shoots, Kincaid had only a trace of starch in the pith and none in the xylem; in the Halbert, starch was fairly abundant in the pith with a trace in the xylem; Burkett had only a trace of starch in both pith and xylem; in Schley it was fairly abundant in both. At the base of the shoots, Kincaid had no starch in the xylem but contained it fairly abundantly in the pith; in both Halbert and Burkett starch was abundant at the edge of the pith but absent at the center and fairly abundant in the xylem; in Schley it was abundant in both pith and xylem. Throughout the varieties no starch was observed in phloem or cortex. Secondary thickenings of pith cell walls appeared to be present wherever starch was present in the cells.

Importance is attached to differences of growth character, anatomical structure and starch content as indicating physiological differences between varieties. The rate or time of, or degree to which carbohydrate formation and storage occurs in trees of a variety may be important in influencing the filling of the nuts of the variety. The "meat" of the nut, formed during late summer, contains materials chemically related to carbohydrates. Whether fats present in the nut are formed from carbohydrates or directly from lower compounds as by the combination of fatty acids with a trihydric alcohol is of course unknown. The presence (3) of a substance, giving some reactions of dextrose in the liquid contained within the seed coat previous to the formation of the "meat" may indicate that the formation of fats is associated with an earlier presence of sugars.

The data and observations presented in this paper are preliminary and not final. They have, however, raised the question—may not the failure to fill of many nuts on trees of some varieties be related to physiological conditions within the tree and characteristic of the variety, rather than directly to imperfections in pollination or fertilization? Further investigations of the matter of filling will consist of physiological studies and of studies of pollination.

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Endosperm and Embryo Development as Related to Filling of Pecans and Walnuts

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IN 1927 McHatton and Woodroof (1) pointed out that a membrane exists in the cavities which are formed in the center of pecan kernels and mentioned that the origin of this membrane was unknown.

Recently it was pointed out in a non-technical article (2) that the cotyledons of pecans and walnuts are folded and the "cavity" in the so-called "half kernels" of the pecan is the space between the folds. Mature nuts which had been examined for that study had no spaces between the folds. The cotyledons were so tightly pressed together that only a double line of epidermis, observable under a microscope, marked the place where the space had been. It was concluded that this epidermis was the membrane to which McHatton and Woodroof (1) referred. Later studies however, revealed that a membrane did exist between the folds of the cotyledons, thus confirming the above observation. This membrane is very thin and in transverse sections of well-filled kernels, in which no vacant space exists, it appears as a part of the outer walls of the epidermal cells. In dissections of boiled pecan kernels, under a binocular dissecting microscope, the membrane may be seen quite plainly. In some varieties which have a large "cavity" in each half kernel the membrane may be observed easily with the naked eye.

The origin of the membrane was determined by a study of the development of the embryo. After fertilization the zygote usually remains dormant until the latter part of July or the first of August in the varieties examined. There is some variation in the time at which the embryos of different varieties begin a rapid enlargement but this usually occurs about the first of September at Stillwater, Oklahoma. The period of rapid enlargement covers approximately 6 weeks. In this time the embryo develops from approximately the 64-cell stage to a full grown embryo which almost completely fills the cavity of the shell. Before the embryo begins its enlargement the integument of the ovule, which becomes the seed coat, has been expanded to the shape and size which it will eventually have as described by Woodroof and Woodroof (4).

The integument is lined with a gelatinous mass of endosperm consisting of very thin-walled cells which are more or less hexagonal in tangential sections. The space inside this endosperm is filled with a clear watery liquid which has an acid reaction and which rapidly reduces Fehling's solution.

The embryo develops with its hypocotyl pointing toward the micropyle and its cotyledons oriented transversely to the septum. (Fig. 1). Early in its development each cotyledon begins to divide into two lobes. The cotyledons are thus divided before they come in con-

tact with the septum. One lobe to each cotyledon grows into the cavity on the other side. Each half kernel is thus made up of half of each cotyledon rather than of an entire cotyledon as Woodroof and Woodroof (4) believed.

The cotyledons are relatively thin at first. They grow close to the inner wall of the integument, following its contour so that the outer face of even the young cotyledons assume the shape of the mature kernels (Plate I, A). The general mass of endosperm is surrounded by them. They continue to follow the walls of the integument in their growth so that eventually even the endosperm in each cavity of the shell is surrounded by the cotyledonary leaves.

Further growth of the embryo is principally a thickening of the cotyledons. The endosperm is absorbed by the cotyledons as they grow but after the contents of the thin-walled endosperm cells have been absorbed there remains a remnant of endosperm consisting of some of the empty thin-walled cells which have been compressed together by the pressure of the growing cotyledons (Plate I, B). This remnant of endosperm is the membrane in question. There are no living cells of the membrane. It is dead tissue which has not been digested and absorbed by the embryo. Some of the cell walls of the endosperm have also been digested and absorbed. It is difficult to explain why all of them were not digested.

The development of endosperm precedes the development of the embryo but it continues to develop after the embryo has begun to grow. Any cultural or climatic factors which interfere with the development of the endosperm will be reflected in the development of the embryo.

It has recently been shown by Sitton (3) that the removal of leaves progressively affects the number of nuts per cluster which can be filled. Sitton also indicated the amount of filling which nuts in a cluster can attain with a given number of leaves. Observations made at the Oklahoma Experiment Station roughly substantiated these findings but they also indicated that the time of removal of the leaves is an important factor.

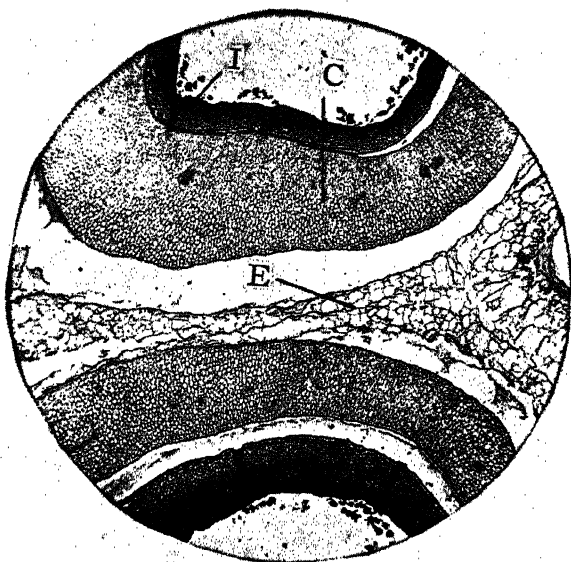
Removal of leaves from shoots after the embryo was approximately one-third to one-half grown did not stop the embryo from enlarging and the consequent filling of the nut. Apparently sufficient food material was present in the nut for the continuation of embryo growth. The fact that the liquid of the vacuole inside the endosperm strongly reduced Fehling's solution indicates that a large amount of carbohydrates are in this area prior to the rapid enlargement of the embryo.

One would hardly expect the hexose equivalent of this liquid material plus the endosperm and the young embryo to be equal to the hexose equivalent of the oily cotyledons of a mature embryo, yet that is what these late defoliation results seem to indicate unless additional carbohydrates move into the nuts from other branches.

When the growth of the embryo has been arrested by insufficient endosperm, the shape of the mature kernels may be exactly the same



A



B

PLATE I

- A. Cotyledons of a pecan embryo. (C_1) first cotyledon, (C_2) second cotyledon, (I) integument.
- B. Endosperm between the folds of the cotyledon. I—integument, C—cotyledon, E—endosperm.

as they would have been if such arrest had not occurred but the space between the folds which had been occupied by endosperm will be vacant except for the membraneous remnant of thin-walled cells. Such kernels are very light, of poor quality, and are disappointing to the consumer.

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Some Characteristics of Pecan Varieties as Determined by Cracking Test¹

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THE data summarized in this paper are based on the characteristics exhibited by the varieties under test regardless of their commercial importance as to production, adaptability, susceptibility to disease or other factors. The planting originally consisted of 28 varieties, but 4, namely, Texas, Sovereign, Mobile, and Appomattox were not considered in this summary because of lack of sufficient data. The test covers a period of 12 years and no variety was considered for which data were not available for a period of at least 6 years.

TABLE I—PECAN VARIETIES ARRANGED IN ORDER ACCORDING TO THE AVERAGE NUMBER OF NUTS PER POUND

Variety	Nuts per Lb.	Per cent Unbroken Halves	Per cent Meat
Monarch.....	59	70	48
Capital.....	61	70	45
Rome.....	63	71	38
Centennial.....	67	74	47
Stuart.....	70	80	48
Teddy.....	71	81	53
Pabst.....	72	78	45
Van Deman.....	72	68	45
Success.....	72	78	53
Alley.....	75	93	50
Moneymaker.....	76	88	46
Frotscher.....	78	95	49
Magnum.....	81	72	45
Randall.....	82	84	47
Delmas.....	85	90	46
Louisiana.....	87	77	42
Senator.....	87	60	47
Schley.....	88	78	60
Russell.....	94	97	55
Teche.....	97	86	45
Mantura.....	97	93	49
Sweetmeat.....	99	74	47
Dewey.....	108	55	41
Curtis.....	109	70	55

The test was outlined as a systematic study of the internal and external characteristics of the 24 varieties studied. The nuts were produced in the Coastal Plain section of the State, where the prevailing soil type is of the Norfolk series. Each bearing year, one pound of nuts was weighed and counted and then cracked with a

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Perfection nut cracker which applies pressure to the ends of the nuts. As cracking proceeded, the number of unbroken, broken and shrunk kernels was determined as well as faulty kernels and empty nuts. Records were made also of the thickness of shell, partitions, texture, kernel condition and quality. The meats were weighed and the percentage determined.

No correlation was found between per cent of meat and annual yield, or between per cent of meat and precipitation for the months of August, September and October. No correlation was found of per cent of meat between varieties. The yield records of a number of the varieties included in this work will be discussed in another paper.

It was found that the per cent of meat varied greatly between varieties and also with the same variety in different years. Schley for example gave a high of 64 per cent and a low of 51 per cent, while the average for the 12-year period was 60 per cent. Dewey with 27 per cent meat in 1917 was the lowest of any variety recorded.

Varieties are arranged below according to the average per cent of meat produced.

<i>50 to 60 per cent</i>	<i>46 to 49 per cent</i>	<i>38 to 45 per cent</i>
Schley	Frotscher	Pabst
Russell	Mantura	Capital
Curtis	Stuart	Teche
Success	Monarch	Magnum
Teddy	Senator	Van Deman
Alley	Sweetmeat	Louisiana
	Randall	Dewey
	Centennial	Rome
	Delmas	
	Moneymaker	

Cracking quality is generally thought of as determined by the number of unbroken halves secured. If this be the case and a standard is adopted based on the percentage of unbroken halves, the varieties fall into the following groups:

Very Good (Above 89 per cent)	Good (75 to 89 per cent)	Medium (70 to 74 per cent)	Poor (Below 70 per cent)
Russell	Moneymaker	Centennial	Van Deman
Frotscher	Teche	Sweetmeat	Senator
Alley	Randall	Magnum	Dewey
Mantura	Teddy	Rome	
Delmas	Stuart	Curtis	
	Schley	Monarch	
	Success	Capital	
	Pabst		
	Louisiana		

Thickness of shell varied little from year to year and there is apparently little or no relation between thickness of shell and the

number of unbroken kernels obtained in cracking. The classification of varieties based on this character is presented below:

<i>Thin</i>	<i>Medium</i>	<i>Thick</i>
Curtis	Mantura	Senator
Russell	Centennial	Rome
Alley	Delmas	Randall
Frotscher	Magnum	Monarch
Schley	Pabst	Moneymaker
Sweetmeat	Stuart	Louisiana
	Teche	Dewey
	Teddy	Capital
	Van Deman	
	Success	

Kernel texture is of considerable interest. So far as this character is concerned, 16 of the varieties were classed as fine-grained, while Capital, Dewey, Frotscher, Louisiana, Magnum, Monarch, Randall, and Rome were coarse. In addition to being coarse, Capital, Frotscher, Louisiana, Magnum, Monarch, and Randall were more or less dry and chaffy. Brightness of kernel is usually associated with fine-grained meats.

TABLE II—ARBITRARY CLASSIFICATION OF VARIETIES ACCORDING TO QUALITY

Excellent	Very Good	Good	Fair	Poor
Schley Centennial	Alley Curtis Delmas	Mantura Moneymaker Russell Stuart Success Teddy Van Deman	Dewey Frotscher Louisiana Monarch Randall Rome Senator Sweetmeat Teche	Capital Magnum

Since quality is largely a matter of personal taste, records were made by a number of workers. It is believed that the classification given in Table II fairly represents the quality and flavor of the meats for the period tested.

Performance Records of Pecan Varieties in North Carolina¹

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IN the fall and winter of 1906 variety tests and experimental blocks of pecans were set out at the Upper and Lower Coastal Plain Branch Experiment Stations.² Approximately 70 trees of 23 varieties were planted at each station. In most cases there were three trees of each variety. In addition, solid blocks of 28 trees each of Stuart, Schley, Van Deman, and Frotscher were set out for pruning, cultural, or fertilizer tests. The trees were set 40 feet apart.

The Upper Coastal Plain Station is located near Rocky Mount, in Edgecombe County, approximately 100 miles north of the Lower Coastal Plain Station, which is near the northern boundary of Pender County near Wallace. The soil on which the groves are located is classed as the Norfolk Sandy Loam, but is deeper, more uniform, more fertile and has been given better treatment at the Upper Station than at the Lower. The trees have made better growth and in general are more thrifty and vigorous. In 1926-7 alternate trees were removed to provide room for the proper development of those remaining. At the Lower Station no trees have been removed except several near buildings or that have succumbed from disease, accident, or other causes.

Many trees at both stations began to bear in 1912, but it was not until 1915 that all the trees had a crop. Consequently, for the purposes of the present report, the first 3 years' yield records have been discarded. Only those varieties which are of commercial importance in North Carolina and those trees on which continuous yield records have been secured are considered here. Schley, Van Deman, and Stuart, are the only varieties of which there are sufficient numbers of trees to give a fair average. Moneymaker and Alley are included for comparison. Schley and Van Deman are apparently poorly adapted to the soils of the two stations, although the trees have received uniform if not the best commercial care. The yields obtained may not be representative of commercial groves in North Carolina, though of course the trees have not been neglected and the groves are located on soils similar to those of the larger plantings in the State.

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²Credit is due former State Horticulturists and their assistants, the Superintendents of the respective Branch Stations and the present organization of the Experiment Station and State Department for accumulating the records and for carrying on the work during the past 27 years.

A summary of the performance records, 1915 to 1931, at the two stations is given in Table I.

TABLE I.—YIELD IN POUNDS PER TREE OF PECAN VARIETIES, 1915 TO 1931

Variety	Lower Coastal Plain					Upper Coastal Plain				
	No. Trees	Average Annual Yield				No. Trees	Average Annual Yield			
		1915-1922	1923-1931	Per cent Increase	1915-1931		1915-1922	1923-1931	Per cent Increase	1915-1931
Schley....	15	2.19	8.93	308	5.76	15	7.84	8.77	12	8.33
Van Deman...	15	1.15	5.52	380	3.46	18	4.36	5.26	21	4.84
Stuart....	18	9.52	13.70	44	11.73	14	8.86	9.80	11	9.36
Alley.....	3	5.81	17.74	204	12.13	1	11.16	44.61	300	28.87
Moneymaker	2	12.58	45.15	259	29.82	2	9.75	45.34	365	28.59
Total	53					50				
Weighted average per tree all varieties.....		4.98	11.45	130	8.41		7.91	9.97	42	8.58

At the Lower Coastal Plain Station, all varieties increased conspicuously in the second period over the first. Increases of the second over the first period ranged from 44 per cent for Stuart to 380 per cent for Van Deman. The increase for all varieties was 130 per cent. The condition at the Upper Coastal Plain Station is quite different. The increases range from 11 per cent for Stuart to 365 per cent for Moneymaker. The average increase per tree for all varieties is only 42 per cent as compared to 130 per cent at the Lower Coastal Plain Station. This seems anomalous since the trees came into bearing earlier and yielded more from 1915 to 1922 (7.86 lbs. and 5.57 lbs.) but the average annual yields per tree were approximately equal at the end of the test (8.58 and 8.41). This is true in spite of the fact that the trees have grown better and in general are larger and have received somewhat better treatment. A partial explanation of this condition is apparent in the following treatment.

ANNUAL DEVIATIONS IN PECAN YIELDS

It is reasonable to assume that pecans should increase in yield annually until full maturity and finally decline. This should be true because of the increasing capacity of the tree as it grows. A pecan tree, however, does not increase uniformly in yield because of several factors, such as, diseases and insects, weather conditions, or a biennial bearing habit. There are deviations even though the general trend is upward. We have assumed, therefore, that the trees being young and the general yield increasing during the

period of our study, a straight line curve would fit the data as well as any and would be a valuable aid in interpreting the yield tendencies. Straight line curves were calculated for the yields of the varieties for the period 1915 to 1931 and the annual deviations obtained. Since the average yields were different, the annual deviations were placed in percentage of the calculated or expected yield.

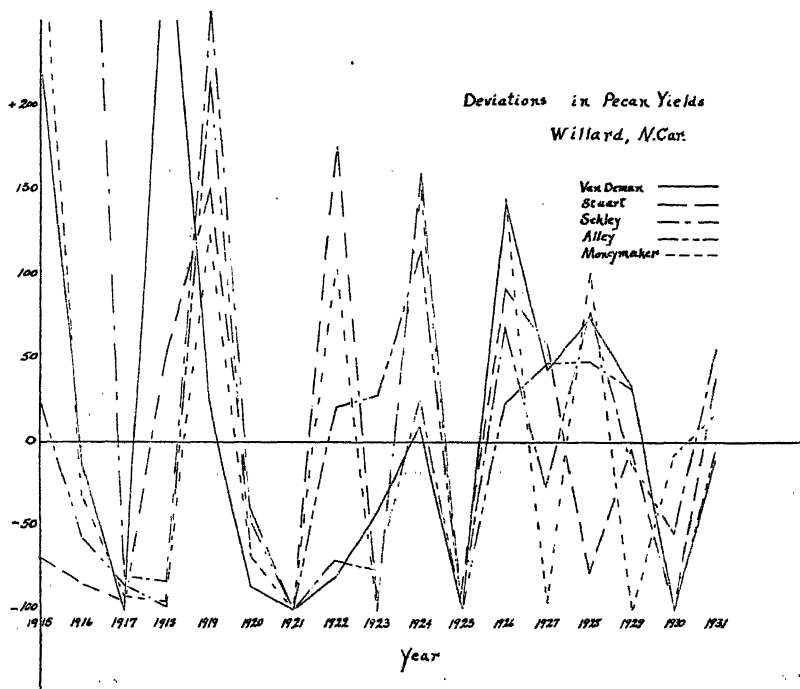


FIG. 1. Deviations in pecan yields at Willard, N. C.

With this treatment the deviations for the several varieties are relative and comparable. These data are presented in graphs.

In certain respects the behavior of the varieties is quite dissimilar at the two stations. At the Upper Coastal Plain Station there is a decided biennial bearing tendency. The significant fact in this regard is that all varieties behave much the same in any year, particularly from 1918 on. The yields at the Lower Coastal Plain Station are not so decided in this respect and we may tentatively assume that weather and growing conditions generally are more favorable here and compensate for poorer soil. The deviations in yield seem not to become much less violent as the trees grow older and the deviations at the Upper Station are generally much greater than those at the Lower Station. The "on" and "off" years do not always coincide at the two stations; in fact the behavior is in most cases opposite. Only in 1918, 1919, 1920, 1924, and 1925 is

there a distinct correlation between the behavior of the varieties as a group at the two stations.

At the Upper Station 1920, 1923, 1925, 1926, 1928, and 1930 are years of complete or practically complete crop failures. The fact that five of these failures occurred in the past nine years explains

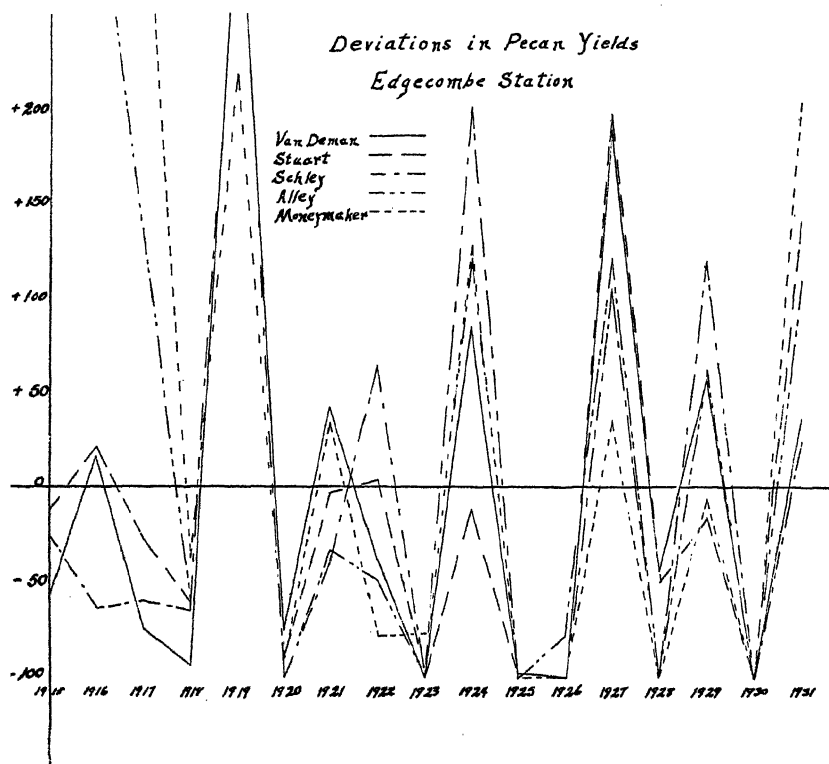


FIG. 2. Deviations in pecan yields at Edgcombe, N. C.

the previous observation that the yields at this Station increased only 42 per cent. At the Lower Station 1921 was the only year of complete crop failure, although 1923, 1925, and 1930 were poor years in the later period, while 1917, 1918, and 1920 were poor years during the first period.

The fluctuations in yield are rather violent and it would seem that it should be a relatively easy matter to associate climatic or other factors with them. There was found to be no correlation between total annual or total summer rainfall and yield. The distribution of rainfall by months also was considered. Not all the monthly correlations were calculated, however, as it soon became evident that the climate of the two stations is subject to violent

fluctuations in precipitation, and that unless certain corrections could be made the data would be of relatively little value. Moreover it is doubtful whether the correlations could be considered of great significance in view of several other very complicated variables which it is difficult to evaluate; for example, the biennial bearing habit, the effect of one season's growing conditions on the following season's behavior, effects of defoliation or twig girdlers on yield, etc. To illustrate this point the following correlation coefficients are given.

TABLE II—CORRELATION COEFFICIENTS OF DEVIATIONS IN WEIGHTED AVERAGE YIELD OF EIGHT VARIETIES AND OF MONTHLY RAINFALL

Station	May*	June	July
Upper.....	$r = +.580$	$r = -.084$	$r = +.673$
Lower.....	$r = +.051$	$r = +.209$	$r = -.456$

Obviously little reliance can be placed in these coefficients when one considers the contradictory relations shown and remembers how close the stations are together. It is true, however, that weather conditions, including frosts and rainfall, are distinctly different at the two stations and we should seek some explanation for the years of total crop failures as for example 1923, 1925, 1926, and 1930 at the Upper Station and 1921 and 1925 at the Lower Station. The most significant years in this respect are 1926 at the Upper and 1921 at the Lower Station. At the respective stations both of these years were "off" years following an "off" year. For the months March to October 1926 at the Upper Station the deficiency in rainfall was 10.99 inches, every month except March and August showing a deficiency. In 1921 at the Lower Station on the other hand there was an excess of 2.16 inches during a like period and the rainfall of 36.9 inches was, according to available record, distributed as uniformly as would be reasonably expected, the greatest variations from normal being -0.63 inch in September and $+1.48$ inches in May. The year 1925 was dry, though not as dry as 1926, and these were "off" and "on" years respectively. The frost records at the two stations, likewise, do not offer an explanation of these tendencies. Thus it appears that although the weather may have and undoubtedly does have an influence on the bearing habit of the pecan tree, other factors which the authors have not as yet been able to evaluate by this treatment of the data are also operating, and all doubtless vary in importance according to the season.

The "filling" of the nuts is also supposed to be associated with weather conditions, particularly rainfall late in the growing season and also early frost. The percentage meat may therefore be a more sensitive index to adverse conditions than total yield. The deviations of percentage meat from the average of the several varieties is given in Table III.

These data indicate Alley to be the most and Stuart the least variable of the five varieties. The most important feature of the table, however, is that in only 4 of the 11 years have the varieties behaved in unison, namely, in 1915, 1917, 1919, and 1927. In these

TABLE III—ANNUAL DEVIATIONS IN PER CENT MEAT IN FIVE PECAN VARIETIES

Year	Deviations in Per cent Meat				
	Schley	Van Deman	Stuart	Moneymaker	Alley
1915	+2	+4	+3	+2	+1
1916	+4	-3	0	-2	+2
1917	-1	-8	-3	-4	-4
1918	+4	-5	0	0	-2
1919	+3	+5	+2	+4	+8
1920	-4	+5	+3	-5	+2
1921	-7	-1	-4	+1	—
1922	+1	-6	0	+1	-5
1923	-8	+5	-1	—	-13
1924	+4	-3	-1	—	—
1925	—	—	—	—	—
1926	+2	-2	0	-3	+1
1927	+3	+4	0	+7	+7
Average per cent meat..	60	45	48	46	51

years the plus and minus deviations in per cent meat coincide with plus and minus deviations in yield which would indicate that conditions favoring yield would likewise be favorable to the filling of the nuts. However, in general, the varieties do not behave uniformly and such a generalization seems unwarranted. The coefficients of correlation of percent meat between three of the varieties are as follows:

Stuart and Van Deman	$r = +.511$
Stuart and Schley	$r = +.097$
Van Deman and Schley	$r = +.329$

The coefficient of correlation between per cent meat and yield of Stuart is $r = +.157$. Obviously, since so little relationship seems to exist between the behavior of varieties it would be quite useless to attempt to associate weather or other conditions, which are themselves extremely variable, with yield, filling or other characteristics of the trees. These data are rather meagre, though they serve, it is believed, as valuable indications of the probable future behavior of these varieties in their respective locations.

From these records and from general observation it seems that the Upper Station is at the northern limit of economic pecan growing in North Carolina, particularly of the long season varieties. It is likely, however, that in regions closer to the coast the limit may be extended somewhat further north.

At the Lower Station the soil and care of the trees seem to be the chief factors limiting the yields. The fluctuations in yield have not been as violent and there have been fewer crop failures than at the Upper Station.

Strawberry Culture in Louisiana

By B. SZYMONIAK, *Fruit and Truck Experiment Station,
Hammond, La.*

THE strawberry is one of the most important crops grown in Louisiana. The total carload shipments in 1923 amounted to 1678 carloads and in 1931 the total carlot shipments for the season amounted to 4720 cars.

The strawberry in Louisiana is grown as an annual. The plants are set out each season during the fall months of October or November and as late as the middle of December. The fruit is gathered from these plants generally in March or sometimes earlier depending on the season. The picking season extends to the last week in May or sometimes to the first week in June.

Plant propagation is one of the most important factors in the culture of strawberries in Louisiana. There are three methods followed in growing plants for fall setting in establishing the main patch.

(Method No. 1). As soon as the harvest is over, the pine straw or other material with which the plants are mulched is removed. The soil is plowed and cultivated to kill weeds and to put the soil into proper physical condition for new plants to take root. A 4-12-4 fertilizer is applied to the plowed soil at the rate of 400 to 500 pounds per acre and the fertilizer is worked into the soil by means of a cultivator. Runner plants are allowed to form in this prepared ground and the best of these new plants are selected and set out in October or November to produce the main crop ripening in March.

(Method No. 2). Strawberry plants are obtained from the North in March or April and set out on plowed land prepared into beds 4 feet wide, and the plants are spaced 15 inches apart. Before the plants are set out, the soil is fertilized with a complete 4-12-4 fertilizer applied at the rate of 400 to 500 pounds per acre. Runner plants formed from the spring set plants are selected and set out in October and November for the main crop.

(Method No. 3). This is known as making plants from July plants. The first runner plants formed in May or June in the producing patch are taken up and reset on freshly prepared land made up into beds 4 feet wide and fertilized with a complete 4-12-4 fertilizer at the rate of 400 to 500 pounds per acre. The plants are spaced 15 inches apart and frequent cultivation is given them to keep down weeds and to keep the soil in proper physical condition. If the season is dry during the months of July and August the plants are irrigated by flooding the middles with water. The first and second plants formed on the July set plants are selected and reset in October or November to establish the main producing strawberry patch.

Comparing the above methods of plant propagation, plants selected from July set plants produced an average of 13.6 crates more berries per acre under identical fertilizer and cultural conditions than strawberry plants set out from unselected plants formed on main producing plants. The best results were obtained from the first plants formed in August. Runner plants developed in September and October on the ends of the runners came into bearing 2 weeks later than No. 1 plants formed on July set plants.

TABLE I—RESPONSE OF STRAWBERRIES TO VARIOUS FERTILIZERS

Treatment N—P—K	Rate of Application (Lbs. per Acre)	Yield per Acre (24-pint Crates)
Nitrogen Test		
6-8-4.....	1212.20	213.2
4-8-4.....	1044.00	208.0
2-8-4.....	912.00	192.4
0-8-4.....	771.40	175.2
Check.....		93.6
Phosphoric Acid Test		
4-16-4.....	1729.00	213.9
4-12-4.....	1368.40	208.2
4-8-4.....	1044.00	202.0
4-4-4.....	733.40	176.8
4-0-4.....	399.00	109.2
Check.....		91.0
Potash Test		
4-8-6.....	1117.20	209.2
4-8-4.....	1044.00	202.0
4-8-2.....	1010.80	216.3
4-8-0.....	957.60	202.9
Check.....		98.2

The other important factor in the culture of strawberries in Louisiana is fertilizer. The kind of fertilizer and the amounts to apply has an important bearing on the yield of berries on our soils which are generally low in fertility.

TABLE II—RESPONSE OF STRAWBERRIES TO VARIOUS RATES OF FERTILIZER APPLICATION

Treatment N—P—K 4-12-4 (Lbs. per Acre)	Yield per Acre (24-pt. Crates)
3000.....	220.4
2000.....	231.4
1500.....	228.0
1000.....	208.0
500.....	190.0
Check.....	91.2

Tables I and II show the results from fertilizer applications, the nitrogen being contained in nitrate of soda; the phosphoric acid, in superphosphate; and the potash, in muriate of potash.

In the test with nitrogen, the 6 per cent nitrogen in a complete fertilizer gave the best results. In the test with phosphoric acid no marked affect on yield of berries was noted. Two per cent potash in a 4-8-2 fertilizer gave the highest yield. The yield was the same where 6 per cent potash was applied and where no potash was included in the fertilizer mixture.

In the test with potash, the best yield was obtained on plots fertilized with complete fertilizer containing 4 per cent nitrogen, 16 per cent phosphoric acid, and 4 per cent potash. Decreasing the phosphate caused a reduction in yield of strawberries on this type soil.

Considering the cost of fertilizer, the best results were obtained from the 4-12-4 fertilizer applied at the rate of 1500 pounds per acre. The fertilizer was made of the following materials:

Nitrate of soda 16 per cent	500 lbs.
Superphosphate 18 per cent	1335 lbs.
Muriate of potash 50 per cent	160 lbs.
Total approximating 1 Ton.	

All fertilizer plots were replicated six times to overcome soil variations as much as possible. The plants received the same cultural requirements and were set out within the same time as nearly as possible, that is within 10 days. The plants were set 1 foot apart in rows 3 feet apart or at the rate of 14,000 plants per acre. The plants were scraped about the middle of January and mulched immediately after, within 10 days time, with pine straw.

On soil types in this section on which strawberries are produced nitrogen and phosphoric acid seem to produce the best results on the yield of berries. Potash does not seem to affect the yields as much as nitrogen and phosphoric acid, the same yields being obtained on plots where muriate of potash was applied as on plots where it was omitted.

Studies on the Effect of Chemical Fertilizers Upon Growth and Fruit Production of the Black Raspberry¹

By W. F. CHERRY, *Purdue University, Lafayette, Ind.*

FOR the purpose of this study Cumberland and Plum Farmer varieties were planted on warsaw loam soil. This soil type was derived from a glacial river terrace where a coarse sandy loam layer overlies a stratum of deep gravel.

Within the past few years some data have been presented on fertilizer experiments with black raspberries which have shown favorable results from the application of nitrogen. The purpose of this paper is to report the results of an experiment conducted at Lafayette, Indiana, in 1930 and 1931 to determine the effect of chemical fertilizers on growth, yield, diameter of cane, and carbohydrate nitrogen relationship.

Thirty-four rows of black raspberries were set in the spring of 1929. The planting was divided into five plots with a check row between each plot. The plots were divided in the center so that the north half of each plot received the same treatment as the south half plus ammonium sulfate.

Approximately 40 tons of manure were applied and thoroughly incorporated in the soil previous to the setting of the plants. Chemical fertilizers as indicated in Table I were applied in the spring before growth started and on September 20, and cultivated into the soil.

The length and diameter of new canes were measured in May, previous to the blossoming period, on July 15, immediately following the fruiting stage, and on November 10, when it was assumed growth had ceased. In all cases ammonium sulfate alone or in combination with phosphorus or potash when applied at the rate of 300 pounds per acre, increased the length and cane diameter over those plots receiving no ammonium sulfate. From a practical point of view this suggests the practice of stimulating growth to secure more vigorous plants.

In a comparison of the yields from the different plot treatments, the 300-pound application of ammonium sulfate shows an increase in yield, with the same diameter, over the treatments receiving no nitrogen fertilizer. This is significant in that it indicates a direct relation between vegetative vigor and fruit production.

The effect of dry weather was of primary importance to the producer in 1930. During this study it was noted that tip burning of the young canes occurred to a very marked degree on the unfertilized, and phosphorus and potash only plots. On the plots receiving am-

¹Submitted to the faculty of Purdue University for the Degree of Master of Science in Agriculture, August, 1931.

monium sulfate either alone or in combination with phosphorus or potash, little or no tip burning occurred. From a chemical standpoint it is assumed that the plants receiving nitrogen were able to manufacture pentosan and protein material in sufficient quantities to hold the water during the time of its greatest need.

TABLE I—AVERAGE YIELD OF PLANTS IN POUNDS OF FRUIT

Treatment	No. Plants	1930	1931
Unfertilized.....	6	4.109	8.239
250 lbs. (sulphate of potash).....	6	4.150	8.827
400 lbs. (20 per cent superphosphate).....	6	7.730	12.490
500 lbs. (sulphate of potash).....	6	4.467	11.203
800 lbs. (20 per cent superphosphate).....	6	6.752	10.618
500 lbs. 2-12-6.....	6	—	11.324
300 lbs. ammonium sulfate.....	6	4.90	12.19
250 lbs. K_2O + 300 lbs. ammonium sulfate.....	6	5.240	13.362
400 lbs. P_2O_5 + 300 lbs. ammonium sulfate.....	6	5.735	13.472
500 lbs. K_2O + 300 lbs. ammonium sulfate.....	6	5.498	16.298
800 lbs. P_2O_5 + 300 lbs. ammonium sulfate.....	6	6.693	15.540
500 lbs. 2-12-6 + 300 lbs. ammonium sulfate.....	6	—	15.871

A comparison of the yield of the plot treatments is given in Table I. An increase in the 1931 yield resulted from the use of ammonium sulfate alone or in combination with phosphorus or potash. Phosphorus, 500 pounds or more, increased the yield whether used alone or in combination with ammonium sulfate. Sulfate of potash, 500 pounds or more, increased the yield either alone or in combination with ammonium sulfate. Complete fertilizer, 500 pounds, did not appear to increase yields over 400 pounds of phosphorus, 500 pounds of sulfate of potash alone or in combination with 300 pounds ammonium sulfate.

For chemical analyses 12 uniform undamaged canes were selected from each of several plots as shown in Table II. Samples of canes, tip growth and leaves were taken July 15 just after fruiting and canes and tip growth December 10, 1930. A composite sample of leaves from the entire cane was used for leaf analysis. The terminal 10 inches of the young shoot and 20 inches at the base of the cane were used for "tip" and "cane" analyses respectively. The leaves, tip, and cane growth were cut into fine pieces and 0.5 grams calcium carbonate added before killing with boiling 95 per cent alcohol. Preparatory to analyses the tissue was dried and ground sufficiently fine in a ball mill to pass through a 100-mesh sieve.

Analyses were made for free reducing substances, sucrose, starch, and total nitrogen. The Quisumbing and Thomas method was used for free reducing substances, Wallerstein Invertase for sucrose, and Taka Diastase method for starch determination. The Kjeldahl-Gunning method was modified for nitrogen

The results of these analyses are given in Tables II and III. The percentage of dry weight was at a minimum in the summer and at a

maximum in December. Free reducing substances varied slightly in the July samples except that the unfertilized plot was low. Free reducing substances in December were less where phosphorus was used and greater where sulfate of potash was used. Ammonium sulfate

TABLE II—COMPOSITION OF RASPBERRY TISSUES JULY 15, 1930, SHOWN AS PERCENTAGES OF FRESH WEIGHT

Treatment	Dry Wt.	Red. Sugars as Dextrose	Sucrose	Starch	Nitrogen
Unfertilized					
Leaves.....	42.70	1.1385	1.4888	1.5230	0.5984
Tip growth.....	34.1163	0.369	0.404	1.3438	0.5415
Canes.....	42.4957	0.944	0.748	1.4903	0.3534
400 lbs. P_2O_5					
Leaves.....	32.91	1.0415	1.310	1.544	1.4674
Tip growth.....	35.9121	0.872	0.736	0.857	0.4604
500 lbs. K_2O					
Leaves.....	39.810	1.0900	1.7365	1.4534	1.2087
Tip growth.....	31.3478	0.800	0.728	1.0993	0.5460
Canes.....	42.405	0.872	0.628	1.3650	0.2172
300 lbs. $(NH_4)_2SO_4$					
Leaves.....	39.9982	1.1385	1.5090	1.6079	1.2827
Tip growth.....	34.6576	0.704	0.856	1.3843	0.4898
Canes.....	41.3140	0.800	0.676	1.1111	0.2923
400 lbs. P_2O_5 , 300 lbs. $(NH_4)_2SO_4$					
Leaves.....	40.8269	1.0415	1.4680	2.6237	1.1884
Tip growth.....	27.5568	0.896	0.879	1.1886	0.5784
Canes.....	44.0449	0.776	0.727	1.1601	0.2945
500 lbs. K_2O , 300 lbs. $(NH_4)_2SO_4$					
Leaves.....	40.8774	1.2105	1.6275	1.6123	1.2336
Tip growth.....	32.6689	1.0415	0.997	1.0682	0.6512
Canes.....	44.136	0.995	0.644	.0963	0.3225

seemed to influence the percentages of these substances but little. Sucrose was highest in July in the leaves from plots treated with sulfate of potash while this substance occurred in greatest percentages in canes treated with phosphorus. Ammonium sulfate tended to increase sucrose slightly in the tip growth sampled in July. In the December samples phosphorus plots produced canes with slightly less sucrose while sulfate of potash seemed to produce more of this substance. Ammonium sulfate influenced the sucrose content very little. Starch was highest in the leaves from the phosphorus and ammonium sulfate plot and varied little in the other plots. Summer tip growth contained a smaller amount of starch where phosphorus was applied. Summer canes produced the least starch where ammonium sulfate was used and slightly higher amounts in the check plot.

Phosphorus tended to reduce the starch content of winter tips, while sulfate of potash tended to increase starch content of these

tips. Ammonium sulfate tended to increase the starch content of winter tips except when in combination with sulfate of potash. Starch was highest in canes from the potash ammonia plot and least in the phosphorus only plot. Nitrogen content decreases from leaves to tips

TABLE III—COMPOSITION OF RASPBERRY TISSUE DEC. 10, 1930 SHOWN AS PERCENTAGE OF FRESH WEIGHT

Treatment	Dry Wt.	Red. Sugars as Dextrose	Sucrose	Starch	Nitrogen
Unfertilized					
Tip growth.....	48.43	2.142	1.3805	1.2173	0.4776
Canes.....	52.05	1.822	2.0525	1.1624	0.4313
400 lbs. P_2O_5					
Tip growth.....	48.29	1.6745	1.5390	0.7787	0.5255
Canes.....	47.77	1.699	2.0365	1.0153	0.4336
500 lbs. K_2O					
Tip growth.....	51.12	2.8095	1.9190	1.4162	0.6019
Canes.....	51.05	1.945	2.4275	1.2550	0.5167
300 lbs. $(NH_4)_2SO_4$					
Tip growth.....	47.90	2.4885	2.0645	1.4817	0.6151
Canes.....	52.0547	1.6845	2.2945	1.2743	0.4997
400 lbs. P_2O_5 , 300 lbs. $(NH_4)_2SO_4$					
Tip growth.....	49.4250	1.160	1.8635	1.1624	0.5221
Canes.....	51.9275	1.493	1.884	1.4938	0.4191
500 lbs. K_2O , 300 lbs. $(NH_4)_2SO_4$					
Tip growth.....	49.3884	3.0295	2.024	1.3818	0.5374
Canes.....	52.8126	2.372	2.391	1.5463	0.4411

to canes in summer growth and from tip to base in winter. Nitrogen was high in leaves from the phosphorus only plot and low in the check. Summer tip growth and canes varied little in nitrogen content. Consistent differences did not occur in the nitrogen content of tips and canes from the various plots in December.

The data indicate that the average amount of total carbohydrates was much greater during the dormant period than during the growing period. Monosaccharides and disaccharides increase as the plant becomes dormant. Under the conditions of this experiment yield and size of berries were closely associated with diameter of canes. Highest yields were secured where ammonium sulfate was used in combination with either phosphorus or sulfate of potash. All three elements increased yields over the no fertilizer plots if used in sufficient quantities. Chemical differences did not seem to be correlated with yield differences. Sugars tended to show higher values in plots receiving sulfate of potash.

Notes on the Fall Flowering Habit of the Red Raspberry

By W. G. BRIERLEY, *University of Minnesota, St. Paul, Minn.*

IN taxonomic descriptions of *Rubus* and of its commonly cultivated species, emphasis is placed on the habit of these plants to develop new canes each year which, in the second growing season, produce leafy shoots on which the flowers and fruit are borne. Although many fall-bearing varieties have been described, the fall-blooming and fruiting habit seems to have escaped attention. Possibly the omission is of no great moment. However, the fall-fruiting of red raspberry varieties has been mentioned more or less frequently since McMahon (4) called attention to it in 1806. Crozier (1) in 1894 described six varieties from *R. idaeus*, seven from *R. strigosus*, and four others which he classed as hybrids. None of these varieties is of any importance at the present time. Darrow (2) in 1917 described the fall-fruiting habit of the Ranere variety, and Hedrick (3) in 1925 described some fall-fruiting varieties.

It seems hardly necessary to cite these descriptions or otherwise to call the attention of pomologists to the fall-fruiting habit of some red raspberry varieties. The fall-fruiting varieties of the past and present seem to establish the fact that this behavior is, in a minor degree, characteristic of the species. However, it does seem to have escaped mention if not the attention of pomologists that at times varieties such as the Cuthbert, typical of the summer-fruiting class, form blossom buds or even set a crop of fruit in the fall at the tips of new canes.

Formation of clusters of flower buds at the tips of new canes of the Cuthbert variety was observed by R. E. Loree and the writer at Grand Ledge, Michigan, in the fall of 1928, but these buds had been killed by frost. In a subsequent discussion of this behavior, S. Johnson of the South Haven (Michigan) Station, stated that in the fall of 1927 he had picked ripe berries from the tips of new canes of the Cuthbert variety. Flowers and fruit have been observed¹ at the tips of new canes of the Cuthbert, at Pullman, Wash., by C. L. Vincent of the Washington Station and at Puyallup, Wash., by some of his students. Obviously the formation of flower buds or fruit is not confined to the fall-bearing varieties. At least the Cuthbert, and perhaps, other varieties, may flower or fruit at the tips of new canes in the fall if seasonal conditions are favorable. Since 1928 the writer has examined many raspberry fields in Minnesota including several varieties, but the fall-flowering or fruiting on new canes has been observed only on the fall-bearing variety Ranere. On the new canes this variety produces its flowers both terminally and in the axils of several of the uppermost leaves. This flowering habit is much the same as that of the lateral shoots arising from the old canes.

¹Noted in correspondence with O. M. Morris, Washington Agri. Exp. Sta., Pullman, Wash.

Some questions which arise from these observations are as follows: Does the fall-flowering at the tips of new canes occur frequently enough to be considered characteristic of the species? Do varieties other than the fall-bearing ones show this fall-flowering behavior at all frequently? Is fall-fruiting more common in localities where temperatures favorable to growth continue throughout October? Has fall-flowering or fruiting been observed in the wild? Answers to these and other questions of like nature will be of interest to pomologists or fruit breeders who are working with the raspberry.

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Growth Studies in the Latham Raspberry¹

By W. G. BRIERLEY, *University of Minnesota, St. Paul, Minn.*

AS a part of a series of investigations relating to the behavior of the Lathan red raspberry, studies were conducted during the season of 1931 to determine the time and rate of growth of the fruiting laterals and new canes of this variety. These studies were carried on at the University of Minnesota Fruit Breeding Farm at Excelsior.

The growing season of 1931 was unusual with respect to abnormally high temperatures and severe drouth. These unfavorable factors seem to have had the effect of retarding growth, particularly in the new canes. However, the primary purpose of these studies was to compare the time of growth in the old and new canes. The unfavorable season does not appear to have affected time of growth so much as rate.

GROWTH OF FRUITING LATERALS

Measurements of the fruiting laterals were started on April 28 as the buds began to push out into growth. From that time until June 22 measurements were made at 4-day intervals except for the period between May 18 and 25, when other work interfered.

One hundred and fifty shoots from the central portion of the canes were selected for these measurements. As a general rule only one lateral shoot was selected per cane and not more than three well developed canes were selected from each normal hill. Measurements were made from the old cane just above the point of shoot insertion to the tip of the shoots until the terminal flower clusters appeared. From that time until growth ceased measurements were made to the base of the pedicel of the terminal flower. Losses due to injury from wind, cultivation, and picking reduced the number of laterals to 129 at the time growth ceased.

Ten laterals were discarded because they were barren. Growth of these barren shoots ceased about May 25 and they were all stunted. They ranged in length from 1 to 10.6 cm., the average being 5.4 cm. Although neither disease nor winter injury were apparent when these shoots were selected it is possible that these causes may have been responsible for their stunted growth.

Low temperature apparently retarded growth between May 6 and 10. On May 6 the maximum temperature was 32 degrees F. and the cold weather continued throughout the 4-day interval. Low temperatures from May 24 to 26 again retarded growth, the effect appearing in the measurements made on May 29.

Blossom buds began to appear on May 18 and were well developed by May 29. The earliest flowers appeared on June 6 when a few of

¹Paper No. 1069 of the Journal Series, Minnesota Agricultural Experiment Station.

the terminal buds opened. By June 14 the majority of the terminal flowers were open and all were open on June 18. Although the development of buds and flowers came when growth was declining in rate, the laterals continued to elongate until the terminal berries began to develop rapidly. The average length of the 129 fruiting laterals and the increases during the 4-day intervals are shown in Figs. 1 and 2.

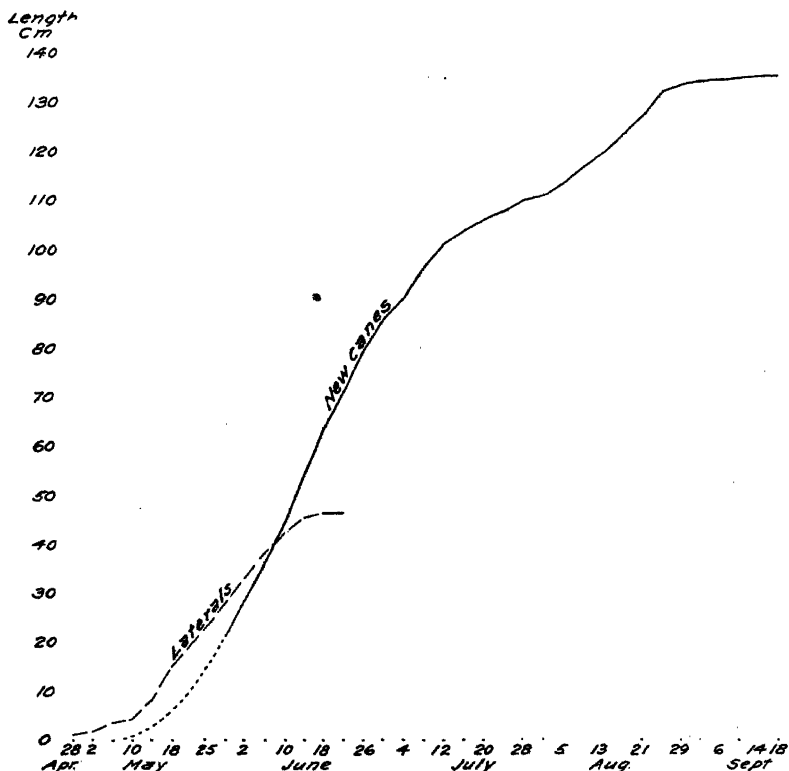


FIG. 1. Growth curves of fruiting laterals and new canes of the Latham raspberry.

GROWTH OF NEW CANES

Measurements of 200 new canes were begun on May 29. Before that date new canes were appearing between the rows. A large proportion of these appeared to be a continuation of growth which began late in the preceding season. New canes from the crowns or under-ground portions of the old canes did not appear to start as early. As it was obvious that only those canes which were located in or very close to the hills could escape elimination by cultivation, the canes for this study were not selected until a sufficiently large number had appeared in the hills.

Measurements were made at 4-day intervals from May 29 until Sept. 18. Each cane was measured from the ground until growth exceeded 100 cm. It was found unnecessary to prepare a fixed point at the bases of the canes as the soil within the limits of the hills was

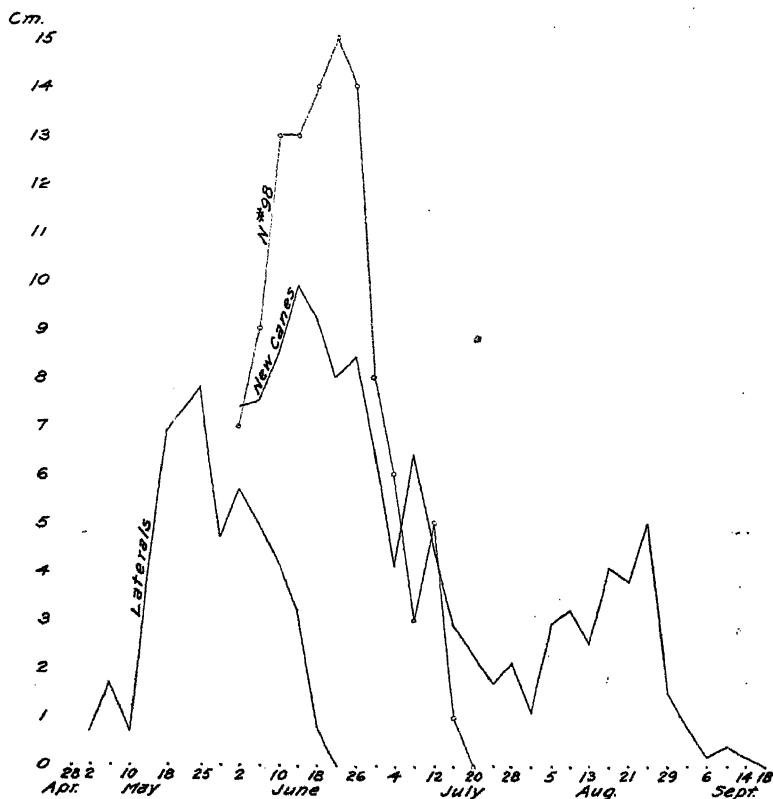


FIG. 2. Seasonal distribution of the growth rate of fruiting laterals and new canes of the Latham raspberry.

not disturbed by cultivation or rain. To facilitate measuring as the canes grew tall enough they were marked with india ink at the height of 100 cm.

Injuries caused by insects, wind, cultivation, and picking reduced the number of canes until only 140 remained on Sept. 18. Grasshoppers caused the loss of 33 of the injured canes. The tender growing tips were eaten and growth stopped. As such injury in nearly every case occurred among the tallest and most vigorous canes the averages computed for each date from the remaining canes must be regarded as below the normal height for the field. Eleven other canes discussed later were not included in the averages. The average height

of the remaining 129 canes and the increases for each 4-day interval are shown in Figs. 1 and 2.

The data shown in the figures mentioned above indicate a definite retarding of growth caused by severe drouth and abnormally high temperatures. Dry weather prevailed throughout June. The cumulative benefit of several light showers is seen in the slightly increased growth recorded on June 26. Cooler weather during this interval also may have tended to increase the growth rate. Between June 26 and 30 daily maximum temperatures reached record high points and severe drying winds accompanied these high temperatures. Although the temperature ranged lower between June 30 and July 4, the drying winds continued. Evidently these conditions brought about the rapid decline in growth observed on these dates. Cool weather prevailed between July 4 and 8, and the cane growth during that period was more than 50 per cent greater than in the preceding interval. From July 8 to the end of the month, the growth rate declined until growth had practically ceased, apparently due to the protracted drouth and high temperature. On July 28, wilting was observed at the tips of a few new canes. Heavy showers occurred on July 31 and August 1, totaling 2 inches of rainfall. The effect of this addition to the soil moisture supply is seen in the immediate increase in growth. Some canes which had made no growth during the preceding 8 to 20 days resumed growth at this time. A later examination of the canes measured showed a marked shortening of the internodes formed during the drouth of July, with longer internodes both below and above those of the drouth period. The hot dry weather evidently caused an early maturing of the foliage on the lower portion of the new canes. On August 21 many new canes had lost all their leaves up to a height of 60 cm. By August 25, many new canes were leafless to a height of 100 cm., and some of the weaker canes retained foliage on only 10 to 15 cm, at the tips. Moderate temperatures and frequent light showers apparently account for the general increase in the growth rate between August 1 and 25. After August 25, the rainfall was again deficient. Drying winds were frequent and at times were accompanied by very high temperatures. These conditions seem to have brought about an early cessation of growth as in this locality the new canes usually continue to make a slow growth until checked by low temperature. The reduction in growth caused by this late season drouth probably was not nearly so great as that caused by the drouth of July.

During the latter part of July and in early August a peculiar performance of some new canes was observed. The growth of these canes was checked rather abruptly and terminal buds were formed. On account of this behavior these canes were not included in the data. Eleven of these canes or 5.5 per cent were noted among the 200 canes studied. Canes Nos. 1 and 98 were typical of this behavior, and their growth curves are shown in Fig. 3. The performance of cane No. 98 is shown also in Fig. 2. With one exception this group of canes made

no further growth. That cane started growth late in the season from the bud next to the terminal one but this growth resulted only in a rosette of leaves.

This formation of terminal buds on a small percentage of new canes may be of frequent occurrence but it has not been observed

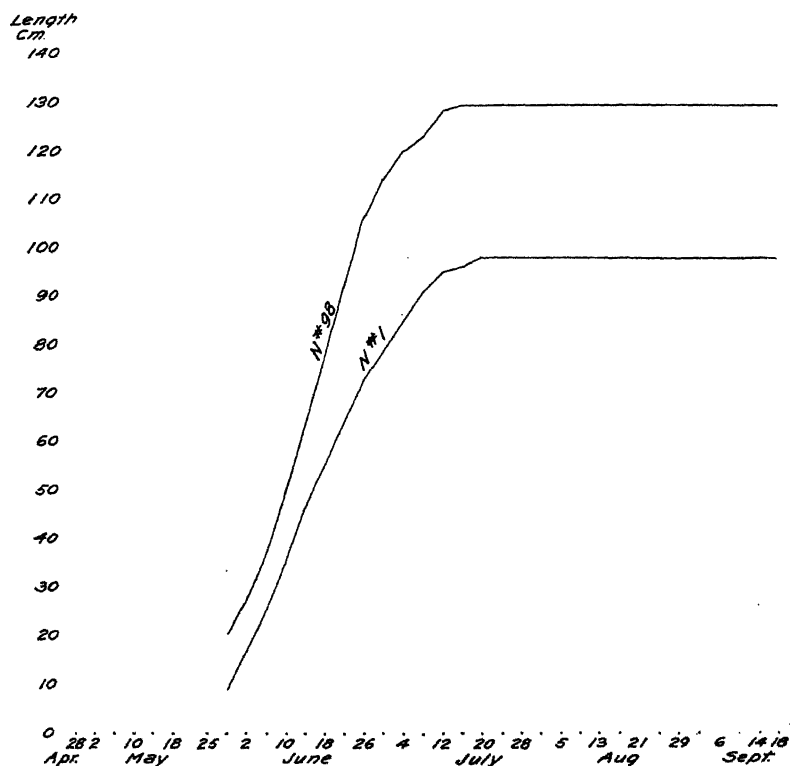


FIG. 3. Growth curves of two new canes which formed terminal buds in mid season.

previously by the writer. It is considered possible that this behavior was due to the unusual heat and drouth.

DISCUSSION AND CONCLUSIONS

The early season until the middle of June may be considered nearly normal. Although there was less than the normal amount of rainfall during that time severe drouth was not effective until late June and in July. Growth during the early season may be considered normal but in late June and throughout July the shape of the growth curves indicate that growth was below normal. Although other factors may have been operating it seems safe to conclude that the deficient mois-

ture supply together with high temperatures and drying winds were mainly responsible for this decline in growth. Further evidence leading to this conclusion is seen in the increase of growth after the rains of July 31 and August 1, and the recurrence of decline after August 25 when drouth again prevailed. Such evidence tends to support the contention that the red raspberry plant is very sensitive to variations in the moisture supply, and to high transpiration as noted by Darrow (1).

The possibility that the old and new canes may actively compete for the food and water supplied by the root, and that this competition may affect the growth rate has often been the subject of conjecture. Although this competition may exist it is not brought out clearly by these data. In Fig. 1 the two growth curves are essentially parallel until the development of flowers and fruit terminates the growth of the fruiting laterals. It may be noted from an examination of the curves of growth rate shown in Fig. 2 that the decline in the rate of the fruiting laterals between June 2 and June 14 is accompanied by an increase for the new canes. This possibly may be evidence that the rapid growth of the new canes affects the growth of the fruiting laterals. However, the decline in the laterals is so closely associated with the development of the flower buds, flowers, and fruit, that it appears likely that this development is more effective in checking growth of the laterals than is the growth of the new canes.

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Transpiration in New and Old Canes of the Latham Raspberry¹

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STUDIES of transpiration in the Latham raspberry were carried on during the growing season of 1931. In these studies the method devised by Heinicke (3) and also the potometer method were used.

In accordance with the method of Heinicke, small weighing bottles containing calcium chloride were attached to the lower and upper surfaces of leaves at the base, center, and tip of both new and old canes in the field. The bottles containing the calcium chloride were dried in an oven for 2 to 3 hours, cooled in dessicators, weighed, and taken to the field. After being exposed on the leaves they were returned to the dessicators and taken to the laboratory where they were weighed immediately. On account of the weight of the bottles and clamps and the small size of many of the leaves only one bottle was attached to a leaf. Normal canes in normal hills were selected so far as possible. Duplicate determinations were made at all times and the results averaged to obtain the data presented in Table I. As it was difficult to find in any one hill two comparable canes of either the new or old growth, the duplicate canes usually had to be selected in adjoining hills. Six bottles, one for each cane region and leaf surface, were attached to each cane. Because of this arrangement the data shown in Table I are not only the averages of leaf positions and surfaces but of the two canes as well.

The time required to place the bottles in position restricted the observations to duplicate determinations. Usually it required about 1 minute to attach each bottle, or 20 to 30 minutes for the 24 bottles used. The exact time of attachment was noted for each bottle and each one was removed exactly 2 or 3 hours later according to the length of time decided on for a given date. On account of this difference in the time of attachment and removal, the periods of exposure were not quite the same and the determinations are not strictly comparable. Obviously the use of additional bottles would have increased the discrepancies.

Observations were made on July 10 and 23 and on August 5, 12, 21, and 29. The results for July 10, August 5, and August 29 are given in Table I. The data obtained on the other dates were so similar to these that they are omitted for the sake of brevity.

These data show some irregularities which may be due to the varying exposure to light and shade, to differences in temperature, or to the time of day. However, there is a fairly well marked tendency

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for the transpiration rate of the lower surface of the leaves to be greater at the tips of the canes than in the central or basal regions. Also there is a marked difference between the rates of the upper and lower surfaces of the leaves, the rates of the lower surfaces ranging from 2 to 15 times greater than those of the upper surfaces. This

TABLE I—TRANSPIRATION OF NEW AND OLD CANES OF THE LATHAM RASPBERRY (Heinicke Method)

Region of Cane	Grams of Water per 100 Sq. Cm. of Leaf Surface per Hour		
	Surface	New Cane	Old Cane
July 10 2-4 p.m. Mean Max. 83 degrees F.			
Base.....	Lower	.37	.43
Base.....	Upper	.07	.09
Center.....	Lower	.59	.26
Center.....	Upper	.04	.08
Tip.....	Lower	.69	.96
Tip.....	Upper	.13	.11
Aug. 5 1-4 p.m. mean max. 94 degrees F.			
Base.....	Lower	.74	.63
Base.....	Upper	.16	.20
Center.....	Lower	1.01	.60
Center.....	Upper	.13	.16
Tip.....	Lower	1.15	.89
Tip.....	Upper	.19	.20
Aug. 29 11a.m.-2p.m. mean max. 66 degrees F.			
Base.....	Lower	.37	.41
Base.....	Upper	.18	.23
Center.....	Lower	.40	.35
Center.....	Upper	.15	.14
Tip.....	Lower	.64	.46
Tip.....	Upper	.23	.26

difference apparently explains the behavior of fruiting canes in the field noted by Kuehner.² He observed that if fruiting canes were bent over at picking time so that the under surfaces of the leaves were unduly exposed to sunlight, the canes tended to wilt, but did not wilt if they were straightened up in a normal position after picking. The water loss from the upper surfaces must be regarded as evaporation as no stomata have been observed in that part of the leaves. The increases in the rate of evaporation from the upper surfaces toward the end of the season may be due to cracking or other injury to the cuticle. The data also indicate a tendency for the transpiration rates of the lower leaf surfaces of the old canes to be less than those of the corresponding surfaces of the new canes as the season progressed.

Studies of transpiration by means of potometers were conducted at 10-day intervals from July 1 to September 9. The apparatus was set up in a greenhouse to avoid the effects of wind movement. Par-

²Mentioned in correspondence from R. H. Roberts, Wisconsin Agricultural Experiment Station, Madison, Wis.

tial shade was provided also as previous experience had demonstrated that excised canes may wilt if exposed to full sunlight and wind. Canes in good vigor and apparently free from disease were cut in the field and the butts immediately placed in water. They then were carried to the greenhouse where they were placed in position in the potometers and the apertures properly sealed.

Observations of temperature, relative humidity, and the volume of water used by the canes were made at hourly intervals. When the observations were concluded the leaves were removed from the canes and pressed to facilitate measuring. The areas were obtained later by means of a planimeter. No attempt was made to measure the surface areas of the canes. The possibility was recognized that the calyx of each flower might transpire to some extent until they dried up at the end of the harvest season, but as the areas were small they were disregarded. After an experience with the wilting of the old cane on July 31 duplicate canes were used. At the close of each series of observations the old and new canes which showed the most regular and comparable behavior were selected for the measurement of leaf areas.

An attempt was made on July 31 to obtain data on the changes in the transpiration rate through the hours of daylight. The wilting of the old cane soon after noon prevented the completion of these observations. Minor difficulties with the apparatus on August 10 prevented the recording of the data during the early morning hours so the work was repeated on August 20. The data obtained at this time are presented in Table II with the transpiration rate calculated in cubic centimeters of water used per 100 sq. cm. of leaf including both upper and lower surfaces.

The performance of these canes and the similar data recorded on August 10, indicates that, disregarding leaf areas, the old canes were transpiring slightly larger volumes of water than the new ones. The total amount of water used for these canes for the time observed was 228.1 cc. and 216.3 cc., respectively for the old and new canes; for the duplicate pair of old and new canes the figures were 182.3 cc. and 172.6 cc., respectively. These figures indicate that old canes 3 weeks after the close of the harvest season are capable of removing at least as much water from the soil as new canes.

Table II, in which these data are presented on the basis of equivalent foliage areas, show that the transpiration rate is somewhat higher in the new cane until 3 p. m. After that hour the rate is slightly higher in the old cane. This behavior is thought to be due to the fact that the foliage of the old canes was all developed by June 22, whereas new foliage is continuously being formed at the tips of the new canes as they grow. The stomatal regulation in these younger leaves may be more sensitive than in the older leaves on the old canes. Attempts were made to observe the behavior of the stomata but this was prevented by the dense mat of hairs on the under surface of the leaves. These data are in harmony with the observations of Darrow (2) to the effect that the growth of new canes of the black raspberry is

checked during the middle of the day because of the expected high rate of transpiration at that time.

TABLE II—TRANSPIRATION OF NEW AND OLD CANES OF THE LATHAM
RASPBERRY
(Potometer Method)

Hour Ending	Temp. (Degrees F.)	Relative Humidity	Transpiration Rates per 100 Sq. Cm. of Leaf	
			New Cane (Cc.)	Old Cane (Cc.)
7 a.m.	66	80	.21	.21
8 a.m.	68	71	.46	.34
9 a.m.	72	67	.56	.48
10 a.m.	77	56	.78	.69
11 a.m.	79	57	.95	.83
12 a.m.	81	48	1.06	.84
1 p.m.	82	45	1.09	.95
2 p.m.	82	45	1.05	.91
3 p.m.	80	44	.84	.78
4 p.m.	79	37	.73	.74
5 p.m.	79	37	.63	.65
6 p.m.	76	48	.43	.52
7 p.m.	73	53	.40	.46

The data obtained throughout the series of observations are presented in Table III in which the transpiration rates are calculated in terms of cubic centimeters of water used per hour per square centimeter of leaf. For the greater part of the time the rates for the new and old canes were almost identical. On July 31, wilting of the old cane lowered the rate materially. No explanation can be offered for the low rate of the old cane on August 10. The lower rate of the old cane on September 9 is thought to be an indication of the decline of the foliage. On account of the dry season the old canes were beginning to decline by September 1, so that the foliage was rapidly losing its normal green color and many of the upper leaves were drying. The data for the new canes for August 20, August 30, and September 9 indicate that transpiration in the red raspberry may fluctuate with the temperature. The data obtained earlier in the season show the same relation to temperature but as the observations were made earlier in the day, comparisons of the rates cannot be made readily with the rates determined later in the season.

DISCUSSION

The principal conclusion to be drawn from these data is that on the basis of equivalent areas there is little difference in the transpiration rate of the new and old canes until late in the season. However, the old canes generally have a much larger foliage area so the total volume of water used is greater for the old canes, at least during July and early August. The earlier decline of the foliage on the old canes may account for the relative falling off for the old canes both in total volume of water transpired and in the rate per unit area. These re-

TABLE III.—TRANSPIRATION OF NEW AND OLD CANES OF THE LATHAM RASPBERRY
(Potometer Method)

Date	Time	Average Temp. (Degrees F.)	Average Relative Humidity	New Cane			Old Cane		
				Leaf Area (Sq. Cm.)	Water Used (Cc.)	Cc per Sq. Cm. per Hour	Leaf Area (Sq. Cm.)	Water Used (Cc.)	Cc per Sq. Cm. per Hour
July 1	9-11 a.m.	86	58	2241.8	50.1	.011	6786.7	147.3	.011
July 11	9-12 a.m.	68	50	1363.6	26.5	.006	4321.2	80.1	.006
July 21	9-12 a.m.	80	49	1664.3	45.9	.009	3180.7	81.9	.008
July 31	8-11 a.m.	80	49	2619.3	73.1	.009	4337.6	45.2	.003
Aug. 10	9-2 p.m.	70	66	2083.2	59.7	.006	3925.5	84.0	.004
Aug. 20	10-2 p.m.	81	49	2345.9	97.7	.010	2733.8	96.7	.009
Aug. 30	11-3 p.m.	69	39	2070.0	65.0	.008	2416.2	77.3	.008
Sept. 9	11-3 p.m.	86	53	1064.5	48.9	.011	1626.3	51.4	.008

sults indicate that the use of non-toxic dyes previously reported (1) may have been a rough measure of the effective foliage areas of the new and old canes.

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Seed and Berry Size of Cane Fruits

By G. M. DARROW and HUGH SHERWOOD, U. S. Department of
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BECAUSE of the importance of seed size in the value of horticultural varieties of raspberries and blackberries, it seemed of interest to obtain some records of seed size to use as a basis for breeding work and for an understanding of the relation of seed size to the economic importance of berries.

Peitersen (1) has given the average seed weight¹ of northeastern species of blackberries and dewberries. They ranged from 1.596 mg. in *Rubus alleghaniensis*, 1.640 mgs. in *R. argutus*, and 1.912 mgs. in *R. frondosus*, to 3.860 mgs. in *R. baileyanus*, the erect growing species having the smaller seeds. Most eastern cultivated blackberries and dewberries are varieties or hybrids of these species.

In the work here reported 10 large berries of each sort were used. The seed weight was obtained by getting the average green weight of the seed of these ten berries. Table I gives the weight of seed of 16 varieties and species of brambles as well as that of 24 selfed seedlings of the Logan. This table also gives records of the average weight of the ten berries, the average number of drupelets per berry, the average weight of seed per berry and the percentage of seed in the berries.

These records show approximately the same maximum weight of seed for the largest seeded sorts as found by Peitersen but a considerably lower minimum for small seeded varieties. The western black raspberry has the smallest seed (1.0754) of those studied; but the Farmer, a cultivated variety of the eastern black raspberry, *Rubus occidentalis*, has seed with 82 per cent greater weight (1.9526). The Cuthbert, an American (*R. strigosus*) x European (*R. idaeus*) cross, and the Lloyd George, a European red raspberry (*R. idaeus*), have approximately the same seed size, 1.4319 and 1.4338 respectively.

Of the blackberry-dewberry group (Eubatus) the wild trailing blackberry, *R. ursinus*, of the Pacific Coast, has the smallest seed (1.3861), being smaller than that of the smallest eastern erect blackberry, *R. alleghaniensis* (1.596). A cultivated variety, Ideal Wild, referred to *R. ursinus*, has seed averaging 1.6681 mg. in weight, or slightly greater than that of *R. alleghaniensis*. The weights for *R. ursinus* are decidedly lower than for others of the blackberry-dewberry group. The seed size of the Lawton (2.302 mgs.) and Stuart

¹A mistake in a decimal period in Peitersen's table is evident, for his weights are ten times too large according to our work. The corrected weights for his records are used here.



PLATE I. Seed of brambles. (1) Young, (2) Evergreen, (3) Himalaya, (4) Nanticoke, (5) Brainerd, (6) Logan, (7) Stuart, (8) Lucretia, (9) Mammoth, (10) Lawton, (11) Plum Farmer, (12) Ideal Wild, (13) Lloyd George, (14) Cuthbert, (15) *R. ursinus*, (16) *R. leucodermis*.

(2.5462 mgs.), both erect blackberries and probably hybrids of *R. alleghaniensis* with some other species, is somewhat larger than that of the erect species as given by Peitersen (1.596 to 2.091 mgs.). Lucretia, derived from eastern species (*R. baileyanus* x *R. floridus*) has an intermediate size, between the dewberries and the erect blackberries; while Mammoth, a supposed *R. ursinus* x eastern blackberry (hybrid), has also a size intermediate between *R. ursinus* and the erect blackberries.

The Logan seed size is nearly twice that of *R. ursinus*, from which it was derived, at least in part, and also nearly twice that of the red raspberry varieties Cuthbert and Lloyd George. The Logan seedlings from self-pollinated seed had seed sizes ranging from 1.7987 to 2.9892 mgs., with an average (2.5288 mgs.) almost exactly that of the Logan, that of the smallest being about 30 per cent less and of the largest 17 per cent greater in weight than that of the Logan. More of the seedlings (16) had seeds smaller while only eight had larger seeds than the Logan.

The Himalaya and Evergreen are cultivated forms of the European blackberry (*Rubus spp.*) and have much larger seed than erect-caned American species. They compare in size with the seed of the American dewberry or trailing blackberry species, which range from 3.453 mgs. in *R. flagellaris* to 3.860 mgs. in *R. baileyanus*. The Brainerd, a hybrid between the Himalaya and a variety of the eastern species, has seed intermediate in size between these forms. The Nanticoke has the largest seed of the erect-caned sorts. It, however, belongs to a very different type of species (*R. cuneifolius*) from those studied by Peitersen and is the American species considered nearest to the European blackberries. Its seed size is indicative of this relationship.

The Young dewberry has the largest seed of those studied (3.8170 mgs.). It is a cross of the Phenomenal with the Austin Mayes dewberry and probably has larger seed than either.

In general, the evidence is that the hybrid blackberries and dewberries (and most varieties are supposed to be hybrids) have larger seed than either parent.

BERRY CHARACTERS

The weight of berries was obtained for use in studying seed size, relative seed weight, and percentage of seed weight. For any variety it is not to be taken as the relative size compared with other berries. Though berries of the Young were heaviest, those of the Mammoth under best conditions may be still larger. Normally, berries of the Lloyd George also average larger than those of the Cuthbert. None of the Logan seedlings in this lot were as large as those of the Logan, though larger fruited selections have been made.

TABLE I—SIZE OF BRAMBLE SEEDS AND FRUITS

Name	Average Weight of Single Seed (Mgs.)	Average Weight of Berry		Average Number of Drup- lets per Berry		Average Weight of Seeds per Berry		Average Percentage of Total Berry Weight Consisting of Seed	
		(Gms.)	Rank		Rank	(Gms.)	Rank	(Per cent)	Rank
<i>Rubus leucodermis</i> ...	1.0754	—	—	103.5	16	.1113	3	—	—
<i>R. ursinus</i> ...	1.3861	—	—	54.9	6	.0761	2	—	—
Cuthbert...	1.4319	2.80	6	85.2	12	.1220	5	4.35	6
Lloyd George...	1.4338	2.75	5	92.2	14	.1322	6	4.80	3
Ideal Wild...	1.6681	2.80	2	44.6	2	.0744	1	3.23	13
Farmer...	1.9526	1.85	1	84.5	11	.1650	11	8.92	1
Lawton...	2.3020	3.55	7	60.6	7	.1395	9	3.93	8
Mammoth...	2.3229	5.88	12	96.0	15	.2230	14	3.79	10
Lucretia...	2.4934	2.74	4	45.8	3	.1142	4	4.16	7
Stuart...	2.5462	4.66	10	70.3	8	.1790	12	3.84	9
Logan (in season)	2.5513	7.22	13	89.6	13	.2286	15	3.16	14
Logan (Aug. 31)	2.3632	—	—	58.1	—	.1373	—	—	—
No. 10 Seedling...	1.7987	3.08	—	64.1	—	.1153	—	3.13	—
No. 16 Seedling...	1.9259	2.38	—	58.1	—	.1119	—	4.70	—
No. 1 Seedling...	1.9824	4.42	—	87.4	—	.1689	—	3.82	—
No. 7 Seedling...	2.0389	2.86	—	59.1	—	.1205	—	4.21	—
No. 12 Seedling...	2.0840	5.04	—	94.0	—	.1959	—	3.88	—
No. 3 Seedling...	2.1697	3.50	—	71.3	—	.1547	—	4.31	—
No. 11 Seedling...	2.2105	3.64	—	58.9	—	.1302	—	3.57	—
No. 20 Seedling...	2.2188	4.33	—	81.8	—	.1815	—	3.75	—
No. 21 Seedling...	2.2391	4.64	—	94.9	—	.2125	—	4.58	—
No. 24 Seedling...	2.3120	4.76	—	68.9	—	.1593	—	3.34	—
No. 9 Seedling...	2.3242	3.54	—	73.7	—	.1713	—	4.83	—
No. 8 Seedling...	2.3365	3.45	—	52.3	—	.1222	—	3.54	—
No. 15 Seedling...	2.3391	3.00	—	63.1	—	.1476	—	4.92	—
No. 22 Seedling...	2.3653	3.08	—	59.4	—	.1405	—	4.56	—
No. 19 Seedling...	2.4049	5.72	—	81.5	—	.1960	—	3.42	—
No. 2 Seedling...	2.5155	5.06	—	96.6	—	.2430	—	4.80	—

No. 6 Seedling....	2.5603	4.45	—	88.7	—	.2143	—	4.81	—
No. 4 Seedling....	2.5746	3.82	—	62.3	—	.1604	—	4.20	—
No. 18 Seedling....	2.5820	4.04	—	72.5	—	.1872	—	4.03	—
No. 13 Seedling....	2.6037	4.17	—	69.4	—	.1807	—	4.33	—
No. 23 Seedling....	2.6603	3.89	—	63.6	—	.1692	—	4.35	—
No. 14 Seedling....	2.6965	4.64	—	61.3	—	.1653	—	3.56	—
No. 17 Seedling....	2.8079	4.03	—	60.4	—	.1696	—	4.21	—
No. 5 Seedling....	2.9892	4.09	—	65.3	—	.1952	—	4.77	—
Seedling average..	2.5288	4.06	—	71.0	—	.1672	—	4.15	—
Brainerd.....	2.6193	4.92	11	83.8	10	.2195	13	4.46	5
Nanticoke.....	2.8924	3.74	8	47.0	5	.1371	8	4.51	4
Himalaya.....	3.0906	4.02	9	47.0	4	.1454	10	3.61	11
Evergreen.....	3.7011	2.70	3	36.8	1	.1362	7	5.04	2
Young.....	3.8170	8.34	14	73.8	9	.2817	16	3.38	12

It is interesting that the wild black raspberry (*Rubus leucodermis*) had the largest number of drupelets per berry. The Mammoth and Lloyd George had nearly as many, while Logan, Cuthbert, Farmer, and Brainerd had more than 80 per cent as many drupelets as *R. leucodermis*.

Though the weight of seeds per berry is given, it is for one condition only. Growing conditions might change greatly the relative size as compared with the total berry weight. The Ideal Wild had the lowest seed weight per berry and the Young the greatest. Seed weight ranged from 0.0744 to 0.2817 gm.

The last column of Table I gives the percentage of seed weight to total berry weight. The Farmer had much the highest percentage of seed weight (8.92), the Evergreen second (5.04), while the Young with the largest seed had a very low percentage seed weight and the Ideal Wild and Logan slightly lower. Berry weights of *Rubus leucodermis* and *R. ursinus* were not taken, but inspection of their seed weights per berry and a knowledge of the fruit indicate that the seed percentage of the former would be high and of the latter low. Only one of the Logan seedlings had as low a percentage as the Logan, while their average seed percentage was almost exactly 1 per cent higher.

Though the percentage of seed weight of the varieties is listed above, it is not a constant and may be expected to vary with conditions. However, percentage seed weights for those with the highest and lowest is considered significant.

RELATION OF SEED SIZE TO SEEDINESS

It should not be concluded that size of seed and percentage of seed to pulp are the only measures of "seediness." In the Young, which has the largest seed size of any in this study, the seeds are not readily noticed, and the Young is sometimes referred to as the "seedless berry." At least two characteristics other than size and seed percentage affect "seediness," namely, the manner of attachment of the seeds to the fibers, and the hardness of the seeds. The Young is not "seedy" because the proportion of seeds to pulp is low, the fibers are attached to the seeds, and the seeds are apparently softer than those of other sorts. Black raspberries are said to be seedy because the seed, though small, are numerous. They constitute a relatively large proportion of the total berry and are separate from the pulp so that they are very conspicuous. One great difficulty with the purple raspberries (crosses of black and red sorts) is that they resemble the black raspberries in seediness. To obtain good shipping and canning berries it is generally considered best to select sorts having berries with many drupelets, hence, many seeds per berry, because the drupelets

in such berries are crowded and grow together. In such instances, large numbers of small seed may be correlated with firmness and hence be desirable. Seed size is, therefore, important even though it is only one of the factors making up "seediness." Proportion of seed weight to total berry weight is probably more important than seed size.

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Use of the Survey Method in Showing Cultural Factors in Red Raspberry Production¹

By JOHN T. BREGGER, *Washington State College, Pullman, Wash.*

THE "survey" is one of the original types of research and dates back in the history of horticultural investigation to the period when the laboratory and the intensive plot methods were as yet unknown or little used. The original intention of a survey meant the analysis of a sufficient number of individual cases to permit logical conclusions being drawn with respect to the success or value of one or more independent practices.

In the discussion to follow, the survey method is being applied to a detailed study in the production and harvesting practices of 69 red raspberry farms in Pierce County, Washington, with an attempt to determine the best practices for growing this fruit. Unlike most surveys, this study utilizes a selected group of growers, since the attempt is made to determine, not so much the normal or average practices, as those practices which are applied by the most successful growers of the industry. The survey includes only bearing fields and all varieties are treated alike.

The information required was secured by two or more calls on each grower, the first at the beginning of the harvest season, when a study was made of the soil, cultivation, fertilization, cover-crops, pruning, training, harvesting, condition of the field, and special practices and problems. A second collection of data was made after yield records and production costs had been tabulated by the growers.

The grower was interviewed personally as far as possible in regard to his cultural practices. At the same time a check was made in reference to the condition of his field. Soil examination, stand counts, methods of training, and similar factors were checked closely by those making the survey.

Soil: The prevailing soil type was sandy loam, ranging from light to heavy. Of the 69 farms finally tabulated,² over 72 per cent of growers had soils which could be classified as sandy loam; 17 per cent silt loam; 4 per cent clay loam; and 3 per cent gravelly loam. In addition one grower each had shot clay and alder bottom. The best yields were found on the silt and heavy sandy loams, and this type of soil was consistently the most important factor in determining

¹Production survey made and results analyzed by the writer in cooperation with Mr. A. M. Richardson, County Agent, Pierce County, Washington; cost-of-production survey made by Mr. R. M. Turner, Farm Management Specialist, Washington State College in cooperation with Mr. Richardson.

²These 69 growers were those of which final records could be completed out of 100 names suggested as the best growers of the industry by the Washington Berry Grower's Association, Puyallup-Summer Fruit Growers' Assoc., and the Hunt Bros. Canning Company.

yields. Practically all fields had good drainage. There existed much variation in the length of time the soil had been under cultivation, ranging from 8 to 75 years, but this seemed to have little effect on present yields. Previous crops harvested appeared to have little influence on yields. The highest production of berries was found on soils which had been built up by turning under legumes with heavy applications of manure.

Cultivation: Of all the production practices considered, cultivation was the least variable. In nearly all cases the grower plowed twice, first towards the plants in February or March, and then away from them in March or April. The depth of plowing varied from 3 to 8 inches, although all growers plowed rather deeply toward the center and shallowly toward the rows. The two highest yields reported were from fields which had always been cultivated deeply, a practice which would be damaging in a field where shallow cultivation had been practiced first. Subsequent cultivations made use of various types of cultivators, and varied in number from 4 to 10 during the growing season, at an average depth of 2 to 4 inches. Weed control and moisture conservation were given as the chief reasons for summer cultivation. There appeared to be some correlation, in cases of growers giving the most cultivation, between frequency and yield. Seventy-seven per cent of the growers ceased cultivation when picking was started, while 13 per cent cultivated at least once after the picking season was over.

Fertilization: All but one of the 69 growers included in the survey used some kind of fertilizer. Over 90 per cent used animal manure, 70 per cent supplementing this with commercial fertilizer. Of growers using manure, about one-third used barn-yard manure, 30 per cent cow manure, 10 per cent horse manure, and 8 per cent sheep manure. Of the growers using commercial fertilizer, most specified 3-10-7. Super-phosphate was used by 25 per cent to supplement the barn-yard manure. About 9 per cent used potash in some form. Only four growers used commercial fertilizer alone.

The consensus of opinion among the growers was that some manure should be used whenever possible to supply humus and nitrogen, and supplement made with phosphate and potash fertilizers when necessary to give the fertilizer proper balance. It was a common practice for growers to apply manure and commercial fertilizers on alternate years, the former being applied during the fall, winter, and spring, and the latter late in the winter or early spring, and usually between the two plowings. Most of the growers were very careful not to apply an excess of nitrogen fertilizer which would stimulate excessive growth and make the raspberry canes more susceptible to winter injury.

Pruning and Training: About half of the growers interviewed preferred to cut out the old canes in the fall, and half in the winter. All, however, believed that the time when this was done made very little difference provided the new canes were mature and the leaves had

fallen. The number of canes left varied from four to eight per hill. Most growers left only strong, thrifty canes, which standard rather than any other determined the number left.

Of the 69 growers, 40 per cent practiced the weaving method of training, 34 per cent the cutting and tying method, while the balance practiced both. The three highest yields were obtained from fields in which the canes were cut and tied, but this fact does not seem particularly significant in favor of that system. Growers reported that both systems required about the same amount of time and one system might be preferable one season, and the other might be better another year. Clean picking was considered easier when the cut-and-tie method was practiced. Training by either method, however, was done in the early spring, after the heaviest frosts were over.

Condition of the field: Fields studied varied in age from 2 to 35 years. Most of them, however, came within the range of 5 to 10 years. A large majority of the fields and stands of plants ranged from 95 to 100 per cent, although a few were as low as 85 per cent. This brought out very forcibly that the high per cent stand is considered a very important factor by the better growers. Little insect and disease injury was recorded in 35 per cent of the fields, but since in some cases these were hard to distinguish from drought injury, there may have been more.

Harvesting: In the frequency of harvesting, there was very little variation. The usual practice was to pick shipping berries three times a week or every 2 days, and canning berries twice a week or every 3 days. In most cases enough pickers had been employed to keep the fields picked clean. Such pickers were carefully supervised, furnished with sleeping quarters, water, light, and fuel, and in some cases food materials. Picking being the most expensive operation in berry growing, was also shown to be the most particular. All growers strive to get the best possible pickers, train them to pick clean and grade closely, and supervise them carefully so as to secure fruit of highest quality for the market. Much of the supervision, as well as picking, is done by women, who in many cases are the wives of the growers.

Most of the pickers are supplied with two-cup bib carriers, together with the six or double-six field carriers for bringing berries to the crate sheds. Emphasis is laid on keeping the field carriers in the shade as much as possible before the picker brings in his fruit. Some growers assign particular rows to each picker and let him keep the same rows all season. This practice is valuable in checking the thoroughness of each picker and in permitting elimination of those not doing good work.

Special practices: Each grower was asked whether or not he had some special practice to which he might attribute his success. A few of the more common or pertinent answers are given here: "Keep ahead of the work; never get behind." "Close supervision." "Timely cultivation together with complete removal of weeds." "Do not over-

TABLE I—COST OF PRODUCTION PER ACRE

	Ave. lb.	1st 10	2d 10	3d 10	4th 10	5th 10	6th 10	7th 10	*See Note
Average Yield (lbs.)	6,234	10,386	7,850	6,916	6,094	5,153	4,280	2,983	
Plowing.....	\$ 7.76	\$ 8.68	\$ 9.90	\$ 7.65	\$ 8.17	\$ 6.65	\$ 5.88	\$ 6.20	%1.49
Applying fertilizer.....	6.87	8.19	7.33	5.39	8.12	6.09	7.86	5.11	1.32
Training.....	11.27	13.23	14.85	9.82	11.91	9.86	8.23	9.89	2.17
Cutting out and burning.....	17.45	22.69	16.88	15.79	19.28	17.50	13.60	14.66	3.36
Hoeing.....	15.03	16.44	14.29	13.39	12.89	16.16	11.97	13.63	2.90
Cultivating.....	9.23	12.09	9.41	9.77	8.71	7.19	9.81	6.74	1.78
Picking.....	174.70	288.53	214.31	184.46	165.20	148.83	110.63	92.47	33.70
Hauling.....	13.51	21.30	17.41	13.33	14.32	9.95	8.62	8.30	2.60
Supervision.....	38.77	63.74	50.89	34.77	33.47	33.62	24.73	26.26	7.48
Fertilizer.....	25.61	28.23	27.57	29.51	25.98	18.07	23.92	23.71	4.94
Crates.....	30.50	53.34	30.37	35.92	33.40	21.90	18.94	16.56	5.88
Material furnished.....	4.80	8.42	4.62	7.46	2.91	3.48	2.65	3.55	.92
Depreciation.....	72.28	75.00	73.72	73.81	71.05	73.18	71.24	70.74	13.94
Interest.....	77.16	91.80	82.80	75.00	77.70	79.80	57.30	68.00	14.89
Taxes.....	12.30	14.25	13.25	11.59	10.40	11.90	11.01	12.55	2.37
Production costs.....	91.84	108.55	100.23	96.32	95.05	81.52	81.27	79.94	18.0
Harvesting costs.....	258.34	435.33	317.42	275.84	249.30	217.78	165.57	147.13	50.7
Fixed costs.....	160.86	181.05	169.77	160.31	159.15	164.88	139.55	151.29	31.3
Total cost per acre.....	518.40	734.93	587.60	522.00	503.51	464.18	386.39	378.37	100.00
Yield—lbs.....	6,234	10,386	7,850	6,916	6,094	5,153	4,280	2,983	
Cost per lb.....	.0855	.05789	.07493	.07687	.08233	.0905	.09021	.1160	

*Note.—Per cent of total average cost. Total acres, 510. Average size farm, 7.4 acres.

fertilize." "Fertilize every year." "Keep the stand up." "Timeliness in all operations."

Cost of production: The accompanying table gives the cost of each item of expense for the entire sixty-nine growers, and the average total acre cost is given for each item, together with the total acre cost and the average cost per pound in each group.

In reviewing the results of this survey several factors might well be emphasized. There is nothing in a production survey of this sort to show that the practices mentioned are the best possible practices which could be employed, but there is a very good indication what practices the best growers have adopted. These growers no doubt started with the best information available at that time, and have discarded some practices and adopted others as they learned by experience or observation. The consensus of opinion of a fairly large number of the most successful growers over a period of years should be a valuable guide in determining a profitable program for berry production.

This survey was intended originally to do no more than bring out the most successful practices now being used in red raspberry cultivation. These have already been brought out in this paper. As soon as the survey had been completed, however, it was found possible to bring out other interpretations, which were not originally contemplated.

Even among what may be considered "best growers," the difference in yields secured is so great that it must be due to something besides the ability of the growers or the practices which they employ. Probably the greatest single factor of this kind is the soil. Where the highest yields were obtained, the soil was practically ideal for berry culture. On poor soils even the best growers, following the best known practices, could not get equal results.

It is brought out very forcibly that the duration of profitable production is not as low as was once thought. It is quite clear, however, that unless the soil is kept built up with plenty of plant nutrients and humus, age might easily be a large factor in the decline of yields.

The desirability of deep cultivation, if practiced continually from the time the field is planted, is brought out. Evidently the advantages of deep cultivation lie in the ability of the berry fields to withstand drought and other adverse conditions, while shallow-rooted plants, more commonly found in shallow cultivated fields, might suffer a severe set-back. Where drainage is good, deep cultivation, through better soil aeration, induces root growth at a lower depth than would be found in a shallow cultivated field.

Annual fertilization stands out as very important. The regularity of fertilization may be even more important, however, particularly if it is of a nature to maintain a high organic matter content in the soil.

High stands of plants and high yields are almost synonymous, other things being equal. When a stand drops as low as 85 to 90 per cent

it may not look very bad, but it can easily account for a 10 per cent decrease in yield. The best growers lay much emphasis on maintaining perfect stands of plants by annual replanting of missing or diseased hills.

One more factor needs considerable emphasis, namely, the quality of the fruit. The best Raspberry grower knows that quality is half the battle of successful marketing, and he is doing everything possible to maintain high quality of fruit. This involves good pickers, close supervision, timely picking, and careful handling of the fruit from the time that it leaves the canes until it arrives at the unloading platform.

This survey, obtained through the fine cooperation of the 69 growers who furnished the information, shows, more than anything else has ever demonstrated, that the success of the red raspberry industry is closely tied up with a good soil location, the very best cultural practices, and much exacting work done at the right time.

Effect of Age of Plant on Flower Production and Yield of Strawberries in North Carolina¹

By E. B. MORROW and J. H. BEAUMONT, *North Carolina State College, Raleigh, N. C.*

GENERAL field observations in the commercial strawberry areas of North Carolina and the results of investigations conducted at more northern latitudes have indicated the value of early-formed plants, but up to this time no local experimental data have been available to demonstrate this point. This paper is a report of results secured during the 1931 season on the relation of age of runner plant to flower and fruit production. The Blakemore, Klondike, and Missionary varieties were used. The work was conducted with the coöperation of Albritton Brothers, Calypso, N. C.

Plants set in December, 1929, were used as mother plants. Runner plants produced in 1930 were pegged down at approximately 15-day intervals, beginning on June 2 and continuing until November 3. There was only a slight variation in the age of plants at each pegging, since only plants just beginning to show white root knobs or with a very few new roots were used. Each mother plant group was limited to four runner series. Two were trained along the row in one direction and two along the row on the opposite side of the mother plant, giving a somewhat double-row hill system. The spacing between the double rows of runner plants was about 12 inches, and the average distance between plants in the runner series was approximately 8 inches.

As the season progressed a number of the plants became infected with nematode (*Aphelenchus fragariae*) causing the "dwarf" or "crimp" disease. The infection was particularly heavy on the Klondike, but it also occurred to some extent on the Blakemore and Missionary. On October 15, 1930, all plants showing apparent signs of the disease were marked. This permitted a comparison of flower counts on diseased and on healthy plants.

Counts of the number of flowers and berries on each individual plant were made just before picking started. This record gave rather accurately the total number of flowers produced, since there was no frost damage and very few flowers appeared after picking started. Records of the number and weight of berries for each age group were kept at each picking. All berries which were below the size requirements for U. S. No. 1 grade were discarded, but the percentage not meeting the size requirements was very small on all varieties. Picking started on May 7 and ended on May 28.

The data for diseased and healthy plants combined are presented in

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Table I and Fig. 1. The results show, in general, that as the age of plant increased, the average number of flowers and berries per plant and the yield per acre increased. The number of flowers and berries per plant and the yield per acre was greatest on Blakemore,

TABLE I—NUMBER OF FLOWERS AND BERRIES PER PLANT, AND CALCULATED YIELD PER ACRE—(B, K, AND M INDICATE BLAKEMORE, KLONDIKE, AND MISSIONARY)

Date Pegged	Average Number of Flowers per Plant			Number of Berries per Plant			Crates (32-Qt.) per Acre		
	B	K	M	B	K	M	B	K	M
MP ¹	113.4	51.3	96.8	46.1	34.0	47.0	396	305	373
6-2.....	94.6	19.7	46.0	46.1	18.3	29.7	426	175	278
6-16.....	86.7	41.5	86.7	39.8	27.2	43.5	406	243	344
7-1.....	88.1	34.0	73.4	39.4	21.4	37.6	367	188	283
7-14.....	81.1	34.7	83.7	36.4	21.6	40.2	356	197	325
8-1.....	66.8	26.8	62.1	32.5	19.0	33.2	326	176	272
8-14.....	55.6	30.9	56.1	29.2	18.7	29.0	308	211	250
9-1.....	36.4	26.7	46.6	21.5	17.7	26.6	239	213	229
9-15.....	29.4	28.1	34.8	18.7	19.1	18.3	224	189	169
10-1.....	20.5	26.0	25.0	13.3	15.8	19.0	153	161	202
10-18.....	18.3	19.0	19.6	12.4	13.7	12.8	142	145	128
11-3.....	8.2	8.5	11.7	6.4	6.2	7.3	91	69	66

¹Indicates Mother Plant.

second on Missionary, and smallest on Klondike. The first decided decline on Blakemore occurred on runner plants pegged August 1. Missionary responded in much the same way. Klondike showed a proportionately lower yield and slower downward trend than either Blakemore or Missionary. Comparing plants rooted September 1 and thereafter with those rooted earlier, the yield from late-rooted plants was proportionately greater on Klondike, second on Missionary, and lowest on Blakemore. Comparing early- with late-rooted plants, the yields were highest on Blakemore, second on Missionary, and lowest on Klondike. These responses indicate that Blakemore withstood summer conditions better than either of the other two varieties, but that it did not retain this superiority to any marked degree after September 1. There was no significant difference between any of the varieties in average number of flowers and berries per plant or in yield per acre on all plants formed September 1 and thereafter.

Weights of the berries from each age group showed a general increase in average berry size as the age of the plant decreased. The size of berry therefore was inversely proportional to the number of berries per plant. This relationship was most pronounced on the Blakemore, but it also occurred on the Klondike and Missionary. The average berry size was largest on Blakemore, second on Klondike, and smallest on Missionary. (See graph, Fig. 1). On Blakemore the percentage of flowers making fruits showed a general increase as the age of plant and number of flowers decreased. Missionary showed the same general trend as Blakemore with the exception of the June 2 plants. Klondike, however, showed no pronounced

upward trend in percentage of flowers making fruits as the age of plant decreased. A study of the data indicates that any increase in percentage of flowers forming fruits is associated with the number of flowers per plant rather than with the age of plant.

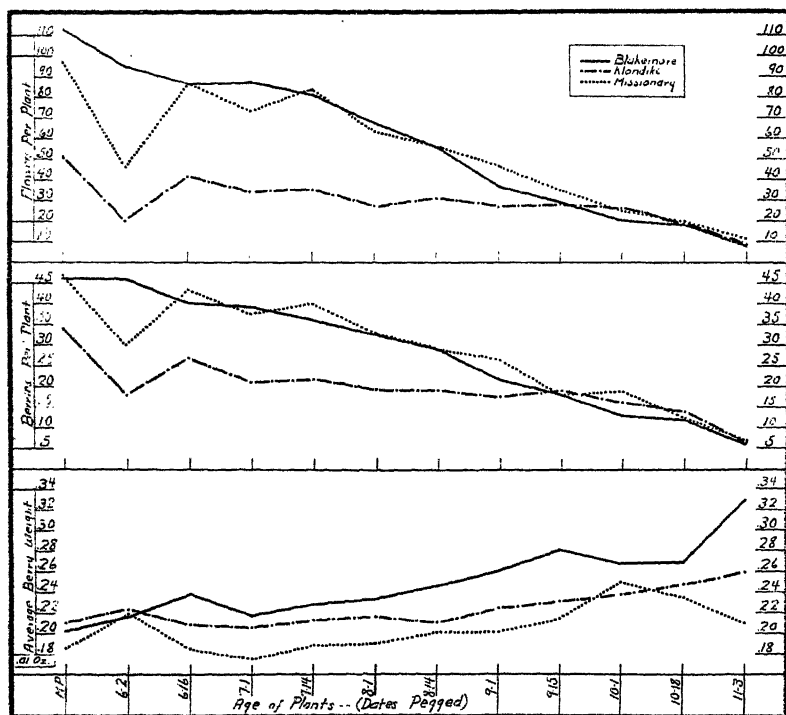


FIG. 1. Number of flowers and berries per plant, and average berry weight as influenced by age of plant.

A comparison of the average number of flowers per plant on diseased and on healthy plants is given in Table II. The general trends for healthy plants are the same as for all plants, but the declines are more regular with the diseased plants eliminated. The very sharp decline on Missionary and Klondike plants pegged June 2 is probably associated with disease. It is possible that a larger number of these plants were affected with disease than the October 15 record indicated. The record shows that 57 per cent of the Klondike plants and 22 per cent of the Missionary plants which were pegged June 2 were diseased. The ratio of the average number of flowers per plant on all diseased plants to the number on all healthy plants of the same age was 34 to 82 for Blakemore, 21 to 38 for Klondike, and 33 to 70 for Missionary. The relatively low yields of Klondike plants pegged during the summer months cannot be entirely attrib-

TABLE II—AVERAGE NUMBER OF FLOWERS PER PLANT ON BOTH DISEASED AND HEALTHY PLANTS

Date Peg- ged	Blakemore				Klondike				Missionary			
	Number Plants	Per cent Plants Diseased	Average No. Flowers Per Plant		Number Plants	Per cent Plants Diseased	Average No. Flowers per Plant		Number Plants	Per cent Plants Diseased	Average No. Flowers Per Plant	
			Healthy	Diseased			Healthy	Diseased			Healthy	Diseased
MP ¹	15	6.66	118.5±7.94	42.0	6	33.33	63.7	19.5	5	—	96.8	—
4-2	19	10.52	99.9±5.35	49.5	7	57.14	21.3	18.5	9	22.22	51.6	26.5
6-10	37	8.10	90.7±3.07	41.3	24	20.83	46.3±2.77	24.8	15	6.66	89.2	51.0
7-1	64	4.68	90.6±2.45	37.3	25	44.00	42.0±2.78	23.8	19	5.26	75.7	32.0
7-14	45	11.11	87.7±2.97	32.8	28	32.14	38.3±2.55	27.2	10	—	83.7	—
8-1	45	13.33	72.6±2.79	32.2	30	36.66	31.9±1.82	17.9	14	7.14	65.2	22.0
8-14	37	5.40	57.8±2.27	17.0	27	22.22	33.8±1.71	20.7	9	—	56.1	—
9-1	24	4.16	37.0±2.98	22.0	26	15.38	28.1±1.79	18.8	16	—	46.6	—
9-15	17	—	29.4±1.70	—	19	15.78	30.6±1.79	15.0	6	—	35.8	—
10-1	27	—	20.5±0.84	—	26	—	26.0±0.92	—	6	—	25.0	—
10-18	24	—	18.3±1.08	—	13	—	19.8±1.11	—	8	—	19.6	—
11-3	14	—	8.2±0.71	—	15	—	8.5±0.65	—	6	—	11.7	—

Indicates Mother Plant.

uted to disease. Flower counts made on healthy plants in a nearby field which was set in Blakemore and Klondike during the first week in August, 1930, gave an average for Blakemore of 71 flowers per plant compared with 35 for Klondike. The average on the plot records for the August 1 pegging was 73 for Blakemore and 32 for Klondike.

The results of this experiment show that North Carolina strawberry growers would profit by following practices designed to secure as many new plants as possible during June, July, and early August. Old beds should be worked out immediately after harvest, and runner plants in new plantings should be permitted to take root during early summer. The data also indicate that yields will be seriously curtailed if the plants are affected by the "dwarf" disease.

Length of the Fruit Development Period of Strawberry Varieties¹

By J. HAROLD CLARK, *Experiment Station, New Brunswick, N. J.*

INFORMATION on the length of the fruit development period of various varieties under different seasonal conditions should be of value to the grower in planning his work, especially just preceding and during the harvest season, to the plant breeder when selecting varieties to be used as parents, and to the horticulturist in making recommendations of varieties for particular locations and environments.

The fruit development period for any particular plant would be, technically, the number of days from the date of fertilization to the date of maturity. It is necessary, however, when working with a large number of varieties to use some more easily observed event which can be rather definitely described and dated. For the purposes of this paper, therefore, the number of days from the date of first bloom of a particular strawberry variety to the date of first picking will be called the fruit development period. This same term was used by Blake (1), working with peaches, for the period from full bloom to height of picking. With many varieties of strawberries, however, it would be hard to fix a date for either full bloom or height of picking.

The data presented in the following tables were secured from the strawberry variety test plots on the horticultural farm of the New Jersey Experiment Station at New Brunswick from 1927 to 1931. Varieties for which no data are presented in 1931 were discarded after fruiting in 1930. The soil was fairly uniform and the plants were in a moderately vegetative condition. All varieties were mulched with straw each winter. Both the 1929 and 1931 data were secured from beds producing their first crop, but some of the 1930 records were taken on beds producing their second crop.

Before presenting the data for a number of varieties the fruit development period of one standard variety, Howard 17 (Premier), will be discussed in some detail, especially in relation to the date of first bloom and to seasonal variations in temperature. Table I gives the dates of first bloom and first picking and the length of the fruit development periods of Howard 17 (Premier) for 5 consecutive years together with the mean temperature during the fruit development period for each of those years. This mean temperature was computed by averaging the mean maximum and the mean minimum daily temperatures.

It will be noticed from Table I that the longest fruit development period occurred during the year of the earliest bloom. The shortest fruit development period occurred during two years, one of which

¹Paper of the Journal Series, New Jersey Agricultural Experiment Station, Division of Horticulture.

was the year of latest first bloom while the other was a year of medium early bloom. This indicates that early bloom is generally associated with a relatively long fruit development period and late bloom with a short fruit development period. This relationship is to be expected because in most seasons the weather will be cooler for a time after early bloom than after late bloom. A similar relationship has been reported by Blake for peaches and by Ellenwood for apples.

TABLE I—DATE OF FIRST BLOOM, DATE OF FIRST PICKING, AND FRUIT DEVELOPMENT PERIOD OF HOWARD 17 (PREMIER), TOGETHER WITH MEAN TEMPERATURE FOR THE FRUIT DEVELOPMENT PERIOD

	1927	1928	1929	1930	1931	Ave.
First bloom.....	5/15	5/10	4/29	5/2	5/4	—
First picking.....	6/13	6/11	6/3	6/2	6/2	—
Fruit development period.....	29	32	35	31	29	31.2
Mean temperature.....	61.5	61.7	60.9	63.3	63.2	—

It is evident from Table I, however, that the fruit development period is not always longer in direct proportion to the earliness of the first bloom. If this direct relationship did always hold, the order of the fruit development periods from longest to shortest would be for the years 1929, 1930, 1931, 1928, 1927. The observed order, however, is 1929, 1928, 1930, 1931, 1927. This difference is no doubt due in part to the difficulty of accurately and fairly setting the date of the first picking. The date recorded was that on which the first commercial picking would be made under New Jersey conditions, which means that enough berries were colored all over and in edible condition so that about one quart could be picked from a 40-foot row. Part of the difference in order, however, is probably due to weather conditions following blooming. In order to give a very rough measure of what the temperature conditions were, without taking up space with a record of daily temperatures, the mean temperature for the fruit development period for each year has been given in Table I. The temperature between first bloom and first picking during 1930 was probably enough greater than that for 1928 to account for the slightly shorter fruit development period in 1930 in spite of the earlier date of first bloom. The temperature for 8 days after first bloom in 1930 was unusually high.

Similar data for a number of varieties have been secured for the last three years and are recorded for part of them, in Table II. The varieties in this table are arranged in the order of their average date of first picking since they are most often classified in this way as early, midseason, or late varieties.

Most of the varieties agree rather closely with Howard 17 (Premier) in the relative order of blooming date and length of fruit development period for these three years. Exceptions may be noted among the late blooming varieties in 1929. Comparing the data for 1929 with that for 1930 it is seen that the range of dates of first

TABLE II—DATE OF FIRST BLOOM AND LENGTH OF FRUIT DEVELOPMENT PERIOD OF VARIOUS STRAWBERRY VARIETIES

Variety	Date of First Bloom			Ave. Date First Picking	No. Days From First Bloom to First Picking		
	1929	1930	1931		1929	1930	1931
Howard 17 (Premier).....	4/29	5/2	5/4	5/1	35	31	29
Missionary.....	4/29	5/2	—	4/30	37	30	—
U.S.D.A. 882.....	4/29	5/3	5/9	5/3	36	29	30
Howard Supreme.....	5/2	5/4	5/7	5/4	34	31	34
Beauty.....	5/2	5/6	5/7	5/5	36	31	32
Mastodon.....	5/11	5/5	5/9	5/8	29	30	33
Joe.....	5/6	5/6	5/9	5/7	35	33	32
Bliss.....	5/8	5/9	5/12	5/10	35	29	27
Boquet.....	5/8	5/8	5/12	5/9	34	30	27
Aberdeen.....	5/2	5/4	5/7	5/4	39	35	35
Lupton.....	5/11	5/9	5/15	5/12	30	31	26
Chesapeake.....	5/13	5/9	5/14	5/12	28	31	27
Aroma.....	5/13	5/8	—	5/11	30	31	—
Redheart.....	5/6	5/5	5/9	5/7	37	32	36
Teddy Roosevelt.....	5/8	5/8	5/15	5/10	38	32	28
U.S.D.A. 875.....	5/11	5/9	5/20	5/13	33	35	25
Parcell.....	5/13	5/10	5/9	5/11	32	34	38
Gandy.....	5/13	5/9	5/17	5/13	33	34	29
Pearl.....	5/13	5/9	5/20	5/14	34	34	29
Wyona.....	5/11	5/9	5/18	5/13	36	35	31
Range.....	4/29 to 5/13	5/2 to 5/10	5/4 to 5/20	4/30 to 5/14	28 to 39	29 to 35	25 to 38
Average all varieties.....					34.0	31.9	30.4

28.7 to 36.5

—

bloom in 1930 is much less than in 1929. This is probably associated with the higher temperatures during the first 10 days of May in 1930. Thus we find 10 of the late ripening varieties beginning to bloom later in 1929 than they did in 1930 although Howard 17 (Premier) and most of the earlier varieties began to bloom later in 1930 than in 1929. It is interesting to note that all but 3 of these 10 varieties had shorter fruit development periods (probably associated with their relatively late blooming) in 1929 although Howard 17 (Premier) and most of the early bloomers had longer fruit development periods in that year. This indicates that probably early blooming of a variety will be associated with a comparatively long fruit development period even when some varieties bloom relatively early and others relatively late during any one year.

There is probably a difference between varieties as regards their response to low temperatures. The data are not sufficient to warrant any conclusions on this, but it appears probable that some of the late blooming varieties may be more sensitive to low temperatures than the early blooming sorts and that this may explain in part some of the apparent inconsistencies in the recorded length of the fruit development period as related to date of first bloom.

The range in time from the average date of first picking of the earliest variety in Table II to that of the latest is exactly 2 weeks. The range in the average length of the fruit development periods, however, is a little less than 8 days. This indicates that the difference in the ripening periods of strawberry varieties must be due, in part at least, to something besides the difference in the comparative lengths of the period between first bloom and first picking. Indeed some of the early ripening varieties have longer fruit development periods than some of the late ones.

It is evident from Table II that the early blooming varieties are quite generally the early ripening ones and that the late blooming varieties usually ripen late. There is some variation, it is true, in the fruit development periods of different varieties, but the question of whether they are to be classified as early, midseason, or late is generally determined more by their average blooming dates than by the average number of days between first bloom and first picking.

During these 3 years, Aberdeen had the longest average fruit development period and Chesapeake had the shortest, although the average date of first picking was the same for both and both are known as midseason or late midseason varieties. It will be noted, however, that the average date of first bloom for Aberdeen was 8 days earlier than that for Chesapeake.

CONCLUSIONS

The data indicate that an early date of first bloom of a strawberry variety will usually be followed by a comparatively long fruit development period, but that unusually high temperatures during this period may shorten it to a point where it may be no longer than it

would ordinarily be after late blooming. The average length of the fruit development period of various strawberry varieties differs somewhat as between different varieties, but a variety with a short fruit development period is not necessarily an early ripening one. Early ripening varieties, however, are usually ones which begin to bloom early and late ripening varieties ones which begin to bloom late.

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Fruit Bud Differentiation in the Dunlap Strawberry in Relation to the Age and Position of the Plant

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FRUIT bud formation in the Dunlap strawberry does not take place in the mother plants and runner plants at the same time, neither does it take place in all of the runner plants at the same time. This variation in time of fruit bud formation is probably due to several factors. The purpose of this experiment was to determine the influence of age and position of a plant on fruit bud formation. Detailed records were kept of the development of each plant from the date of rooting until it was removed from the field. A morphological study was made of the floral development of each plant. These data were then used to determine the influence of the age and the position of a plant on its floral development.

On April 25, 1928, 80 uniform Dunlap strawberry plants were selected and set 4 feet apart in rows 5 feet apart in a fertile sandy loam soil. The plants were placed under irrigation in order that they might not suffer in case of protracted dry periods.

During the growing season of 1928, all flowers were removed as soon as visible from the young mother plants. The plants were kept free of weeds and were cultivated at least once each week. They were watered on April 25 at the time of planting, on June 3, and on August 6. The amount of water applied approximated $\frac{1}{4}$ -inch of rainfall with each irrigation. Each individual mother plant was limited to five unbranched runner series. All other runner plants were removed as soon as noticed. By a runner series is meant the runner plants in a single connected string of plants arising from the mother plant.

A record was kept of each individual runner plant. As a new plant showed the first white root knobs it was considered as set and was fastened to the ground by means of a Greening pin. An oat straw mulch was applied November 15, 1928, and was removed April 15, 1929.

Plants were removed from the field on the following dates, August 27, September 10, October 5, and October 25. Only the buds at the apex of the crowns of the plants were used for morphological study. Standard histological methods were used in the preparation of the buds for sectioning and photographing.

Table I gives the variation in days for the time of setting of plants in a given position and also the average age in days of plants dug. It will be noted that there is an interval of 46 days between the setting of the first No. 1 plant and of the last No. 1 plant. The greater percentage of these No. 1 plants, however, set during a 7-day period. The number of days from this period to the various dates of digging is an approximation of the age of the No. 1 plants. The same method

TABLE I—VARIATION IN DAYS BETWEEN THE SETTING DATES OF PLANTS IN A GIVEN POSITION, THE AVERAGE AGE IN DAYS OF PLANTS DUG ON DIFFERENT DATES, AND THE DATES OF FLOWER DIFFERENTIATION

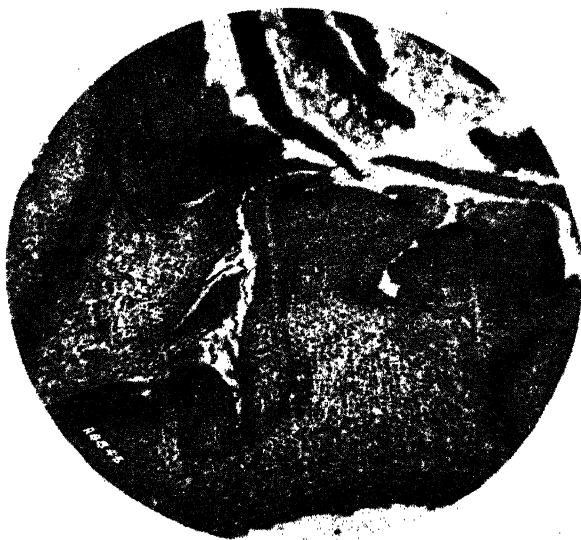
Position of Plant	Interval in Days between the 1st and Last Plant to Set at the Position Designated	Average Age in Days of Plants when Dug. Dates Based on Periods of Maximum Rooting for the Position Specified				Period During which Differentiation Occurred
		Aug. 27	Sept. 10	Sept. 20	Oct. 5	Oct. 25
Mother plant.	0	124	138	148	163	183
No. 1 plant.	46	63	77	87	102	122
No. 2 plant.	59	49	63	73	88	108
No. 3 plant.	56	42	56	66	81	101
No. 4 plant.	56	35	49	59	74	94
No. 5 plant.	71	21	35	45	60	85
No. 6 plant.	54	14	28	38	53	73
No. 7 plant.	71	—	14	24	39	59
No. 8 plant.	64	—	—	10	25	50
No. 9 plant.	50	—	—	—	11	31
No. 10 plant.	35	—	—	—	—	10
						Sept. 10 to Sept. 20
						Sept. 10 to Sept. 20
						Sept. 10 to Sept. 20
						Sept. 10 to Sept. 20
						Sept. 20 to Oct. 5
						Sept. 20 to Oct. 5
						Sept. 20 to Oct. 5
						Sept. 20 to Oct. 5
						Oct. 5 to Oct. 25
						Oct. 5 to Oct. 25

was used in determining the ages of the plants at the other positions. All mother plants were set on the same date so their ages are the same at each date of collection.

It will be noted from this table that 138 was the greatest number of days to elapse before differentiation was noted, whereas, the shortest number of days between the rooting of a plant and observation of the differentiation of the floral parts was only 10 days. The No. 1, 2, and 3 plants all showed fruit bud formation between September 10 and 20, although their ages were 138, 77, and 63 days, respectively. Plants at positions 4, 5, 6, 7, and 8 on the runner series had differentiated their buds by October 5. The ages of such plants varied from 74 to 25 days on this date. These plants varied very slightly in their degree of differentiation on this particular date. On October 25 all plants, with the exception of the very youngest, the 9's and 10's, were quite similar in the stage of development attained in their primary flowers. The flowers of the youngest plants developed rapidly in the latter part of the season. The flowers of these younger plants reached a stage of development similar to the October 5th stage of the older plants. It was found on October 25 that the mother plants and No. 1 plants had the highest degree of floral development and were followed very closely in order by the other plants on the runner series up to the number nine plants.

Flower bud differentiation took place regardless of the age of the plant. For example, the flowers of the primary stalks of the No. 10 plants on October 25, 10 days after setting, were as far advanced as the flowers of the central stalks of the mother plants on September 20, 148 days after setting. A similar stage of development was reached in the No. 2 plants on October 5, 88 days after setting (Plate I). The development of the flowers differentiating later in the season was evidently more rapid than the development of those differentiating earlier in the season. Hill and Davis (1) report that the Pocomoke variety differentiated the buds of runners 4 weeks and 8 weeks of age on September 19. Runners rooting after this date showed signs of differentiation when only 2 weeks old.

The influence of the position of a plant in relation to fruit bud formation was studied on those plants which had rooted at the same time, but occupied different positions on the runner series. The evidence obtained pointed to the fact that those plants in positions closer to the mother differentiated the central floral stalks earlier, and gave evidence of more advanced floral development during the earlier dates of collection than those plants which were of similar ages but more distant from the mother plants. This was not apparent on the late formed runner plants because these plants formed fruit buds in a shorter period of time and developed the central flower stalks quite rapidly. Therefore, with the exception of the youngest plants, the stage of floral development attained by the flowers of the late formed runners was quite similar, even though these plants were of similar ages but of different positions. The flowers on the central



A



B

PLATE I.

- A. Mother plant set April 25, 1928, age 148 days. Sepals clearly seen and petals barely visible on primary flowers.
- B. Plant No. 10 on runner series, rooted Oct. 15, 1928, age 10 days. Sepal and petal primordia visible on primary flower, secondary flowers evident.

floral axes of buds of the earlier formed runner plants occupying positions 1 and 2 on the various runner series showed a higher stage of floral development on the same date than did the flowers of plants of the similar ages occupying positions 3 and 4. It is questionable whether this was due to the fact that the more rapidly growing runner series was more vegetative and consequently floral development was delayed or whether the less vegetative runner plants differentiated buds more quickly. For example, in a comparison of a few runner series, some of which had No. 2 plants and some of which had No. 3 plants of the same age, the formation of the fruit buds was delayed on the No. 3 plants. This might be due to the fact that the runner series, which set three plants, while the others were setting only two plants, were in such a state of vegetative vigor as to cause a delay in the formation of fruit buds.

The early set runners make the strongest plants and differentiate their buds first. It would seem feasible to expend extra effort in getting an early set of runner plants and to thin out a greater number of those plants formed late in the season.

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The Relation of Fertilizers to Respiration and Certain Physical Properties of Strawberries¹

By E. L. OVERHOLSER and L. L. CLAYPOOL, *State College of Washington, Pullman, Wash.*

THAT spring applications of nitrogen fertilizers have a distinct effect on the physical and chemical structure of the strawberry fruit was indicated in studies by Shoemaker and Greve (13) with the Premier variety. Studies herewith reported were made this past spring at the Irrigation Branch Experiment Station, Prosser, Washington, to determine the possible relation of fertilizers to certain properties of strawberries.

The properties studied as influenced by the application of fertilizers were: (1) respiration intensity, and respiration ratio (carbon dioxide evolved divided by the oxygen absorbed); (2) firmness of texture; and (3) electrical resistance of tissue.

MATERIALS AND METHODS EMPLOYED

Clark seedling strawberries growing upon a medium sandy loam soil that has been fertilized during the preceding year and in February of the same year were employed. The different individual plots had received the elements as follows: N, "extra N", NP, P, and the check, the latter receiving no fertilizer applications. The N plot received ammonium sulphate at the rate to supply 30 pounds of actual nitrogen per acre in March, 30 pounds in June, 1930, and 30 pounds in February, 1931. The second N plot, known as the "extra nitrogen" plot received a larger application amounting to 106 pounds of actual nitrogen per acre in the spring of 1931 instead of 30 pounds as did the other nitrogen plot.

The phosphorus plot received superphosphate at the rate to supply 36 pounds of actual phosphorus per acre in March and again in June, 1930, and in February, 1931. The phosphorus and nitrogen plot received the combined elements in the same forms, amounts and dates of applications.²

The respiration intensity was determined as previously indicated (12) except that the respiration chambers were 2-quart fruit jars and the average size of each individual sample of berries was 39 specimens, weighing about 149 grams. The berries of each harvest were picked at as nearly the same stage of maturity as was feasible, as judged by color, but an attempt was made to have each sample

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²The writers wish to acknowledge the aid and coöperation of E. C. Durdle, County Agent, Benton County, Washington, who arranged for the plots and applied the fertilizers.

representative of each plot with respect to size of individual berries. There were consistent differences in the average size of the berries from each plot and, therefore, an attempt was made to select samples of the same size from each plot. The samples, however, were selected so as to be representative of the average size of the fruit for the plot.

TABLE I—THE EFFECT OF FERTILIZERS UPON RESPIRATION INTENSITY OF CLARK SEEDLING STRAWBERRIES

Fertilizer Treatment	Harvest Date	Average Duration Respiration Interval	Average Temperature During Experiment	Number Respiration Periods Det.	Average Respiration Ratio	Average Mgs. CO ₂ Produced per Kilo Hr.
Check (no fertilizer)	May 18	19.68	19.4	6		100.97
Check.....	May 22	14.88	20.1	6		91.50
Check.....	May 26	12.35	20.2	6		109.90
Grand average..		15.64	19.9	18	0.959	100.79
Nitrogen.....	May 18	16.06	18.9	6		110.06
Nitrogen.....	May 22	12.84	19.8	6		103.12
Nitrogen.....	May 26	11.83	20.0	6		115.39
Grand average..		13.58	19.6	18	0.968	109.52
Extra nitrogen....	May 22	15.18	20.1	6		121.60
Extra nitrogen....	May 26	12.40	20.1	6		119.05
Grand average..		13.79	20.1	12	0.968	120.33
Phosphorus.....	May 18	18.49	19.1	6		86.20
Phosphorus.....	May 22	14.44	20.0	6		95.05
Phosphorus.....	May 26	15.00	20.1	6		107.53 ¹
Grand average..		15.00	19.7	18	0.948	96.26
Nitro. and phos....	May 18	16.65	18.7	6		94.06
Nitro. and phos....	May 22	13.68	19.6	6		93.21
Nitro. and phos....	May 26	12.08	20.0	6		105.86 ¹
Grand average..		13.59	19.4	18	0.957	97.71

¹Berries somewhat soft and ripe.

Strawberries from the "extra nitrogen" plot were the largest in average size; those from the nitrogen, nitrogen and phosphorus, check, and phosphorus, ranked as given in descending order of average size. Usually other factors being equal, the smaller the average size the greater the respiration intensity, since a larger surface area per volume of tissue is exposed.

The resistance measurements of the tissue were made with a combined resistance box and Wheatstone bridge with an alternating current 60-cycle galvanometer by balancing the unknown with the known resistance. The electrodes were two rectangular pieces of platinum iridium imbedded in Bakelite and projecting 5 mm. The electrodes were standardized in N/50 KCl at 20 degrees C., and the readings converted to specific resistance. The resistance measurements were

made at two opposite points on the surface of the fruit by plunging the electrodes their full length into the flesh at right angles to the surface (11).

RESULTS

Effect upon respiration intensity: The apparent differences in the respiration intensity of strawberries from the different fertilizer plots when harvested at as nearly the same stage of maturity as was feasible is shown in Table I.

The average respiration intensity of strawberries from the nitrogen plot was nearly 10 per cent higher than that of comparable lots from the check plots receiving no fertilizer application. The respiration intensity of berries from the plot receiving the larger amounts of nitrogen was nearly 20 per cent more than fruit from the check plot.

TABLE II—THE EFFECT OF FERTILIZERS UPON FIRMNESS OF THE TISSUE

Fertilizer Treatment	Number of Pickings, (Averaged)	Number of Pressure Determinations (Averaged)	Acreage Pressure (Grams)
Check (no fertilizer)	3	168	177
Nitrogen	3	168	161
Extra nitrogen	3	112	120
Phosphorus	3	168	168
Nitrogen and phosphorus	3	168	165

The application of phosphorus both alone and in combination with nitrogen appeared to slightly depress respiration intensity. In this connection Lagatu and Maume (6) concluded from work on grape leaves that the assimilation of phosphorus served as a check on the assimilation of nitrogen. Larson (7) found with apple trees that when the percentage of nitrogen was high in the leaves, the percentage of phosphorus was low and when the percentage of nitrogen was low the percentage of phosphorus was high. In view of these findings it is possible that if an increased amount of nitrogen present in the fruit results in greater respiration intensity, that application of phosphorus may lower the respiration intensity, by tending to depress the nitrogen intake. No chemical analyses of the fruit were made this year.

The respiration ratio was higher the higher the respiration intensity, but the values averaged below unity.

Effect upon firmness of flesh: Using the method of Hardy and Locklin as previously described (12) the firmness of the strawberries was expressed in grams of pressure necessary to force a $\frac{1}{8}$ -inch plunger through the flesh to a depth of $\frac{3}{16}$ of an inch. Two penetrations per berry of 28 berries representative of each lot were averaged. The data are shown in Table II.

The firmness of the berries from plots receiving nitrogen and phosphorus either singly or in combination was lower than those from the check plots. The berries from the nitrogen plots tended to be

appreciably softer and those from the extra nitrogen plots much softer than those from the check plots. The data by Shoemaker and Greve (13) indicated that berries from plots receiving nitrogen were slightly softer than those from check plots.

Brown (2) has urged moderation in the use of nitrogen fertilizers upon strawberry plants. When the weather was warm during the picking season plants receiving very heavy nitrogen applications produced berries inclined to be soft, if not picked promptly and carefully handled. Even those handled as suggested apparently did not possess long keeping and shipping quality.

Auchter and Knapp (1) mention that quickly available nitrogen fertilizers, especially if the applications are heavy, result in soft and green berries, particularly if the season is wet. This is in agreement with observations by Chandler (3), French (5), Loree (9), and Colby (4).

TABLE III—THE EFFECT OF FERTILIZERS UPON ELECTRICAL RESISTANCE OF THE TISSUE

Fertilizer Treatment	Number of Pickings (Averaged)	Number of Determinations (Averaged)	Average Specific Resistance in Ohms
Check (no fertilizer).....	3	168	7347
Nitrogen.....	3	168	6992
Extra nitrogen.....	2	112	6820
Phosphorus.....	3	168	7969
Nitrogen and phosphate.....	3	168	7308

The results of Shoemaker and Greve (13) indicated that early spring applications of nitrogen fertilizer in fruiting years tended to make the fruit softer. Their results, however, did not seem to indicate that the fruit was so soft or of such inferior handling quality as to preclude the spring use of nitrogen if such treatment would otherwise improve the crop.

Effect upon electrical resistance of the tissue: The differences in the texture of the fruit were measured by using electrical resistance in ohms as employed by Latimer (8), and Overholser (11). Latimer, using methods primarily of Osterhout (10) found with fruits of pears that decreased resistance accompanied greater maturity and the attainment of senescence.

The specific resistance order seemed to be more nearly inversely correlated with respiration intensity than was the firmness of flesh as measured by the pressure tester. This apparent non-relationship between firmness of flesh and respiration is in agreement with previous work (12), indicating that firmness of flesh of strawberries is apparently not directly correlated with low respiration intensities.

The berries from the extra nitrogen plots having the highest respiration intensity had the lowest specific resistance; and the fruit from the nitrogen plot, averaging next highest in respiration intensity averaged next lowest in specific resistance. The fruit from

the phosphorus plot averaging lowest in respiration, averaged highest in specific resistance.

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The Effect of Fertilizer on the Quality and on the Keeping and Carrying Qualities of Strawberries

By W. D. KIMBROUGH, *Louisiana State University, Baton Rouge, La.*

ABSTRACT

The complete paper will appear as a bulletin from the Alabama Agricultural Experiment Station.

VARIOUS fertilizer treatments were applied in the spring of 1929 to plots of the Aroma strawberry to study the effects of fertilizer, especially nitrate of soda and potash, on the berries. Quality studies were based on the moisture, acid, and sugar contents of the berries. The results obtained indicated that moderate applications of nitrate of soda had no injurious effect on the berries. Heavy applications of nitrate of soda under some conditions had a slightly adverse effect on the berries. No effects beneficial to the fruit were found from the application of potash.

Transpiration Studies on Strawberries¹

By GEO. M. DARROW, and HUGH SHERWOOD, *U. S. Department of Agriculture, Washington, D. C.*

IT has been apparent to the senior author for some years that one of the most important production problems of the strawberry is drought resistance. In some years the decrease in possible production due to less than optimum moisture may be 50 per cent or more. Though attack on the problem has centered largely on the breeding of drought resistant varieties, an understanding of the response of the plant to conditions affecting water losses has been sought as a basis of the breeding work, since varieties, drought resistant under some conditions, are not relatively as drought resistant under other conditions. The results of certain phases of the work are here reported. Though work is being carried on in the field, most of the following experiments were with vigorous plants in 5- and 6-inch pots in or adjacent to the greenhouse. When the experiments were begun, the plants were transferred to pots which were paraffined on the outside and the soil was covered with paraffin or waxed paper to prevent evaporation from the pot or soil. Additional water was supplied to the pots as needed.

RELATIVE TRANSPIRATION FROM OLD AND NEW LEAVES

To test the relative rate of water loss by transpiration from old and new leaves, six plants of the Ettersburg 121 variety were used. Leaves of this variety live longer than those of most other sorts and the old leaves used were several months old. The leaf area of all six plants was reduced to equal amounts, 171.5 sq. cms. On three plants the old leaves were picked off and only young, fully expanded leaves which were still light green were left. On the other three the young leaves were picked off and only the oldest healthy leaves were left. The three old-leaf plants had in all about 11 leaves and the three young-leaf plants 18 leaves.

Records of the water loss per plant by weight were obtained by periods from July 31 to August 24. The total water loss for each plant was as follows:

	<i>Plant 1</i>	<i>Plant 2</i>	<i>Plant 3</i>	<i>Ave.</i>
Plants with old leaves.....	1327 cc.	1132 cc.	1255 cc.	1238 cc.
Plants with young leaves ...	1302 cc.	1290 cc.	1299 cc.	1294 cc.

Thus, the plants with young leaves averaged less than 5 per cent greater moisture loss than those with old leaves. However, considering that one old-leaf plant lost more and one lost less than any young-leaf plants and that the young-leaf plants had more, though smaller,

¹Facilities for conducting these investigations were furnished through the coöperation of the Oregon Agricultural Experiment Station.

leaves, there is no evidence that old and young leaves of this variety under the conditions of the experiment differed significantly in their transpiration rates.

The average water loss per plant for comparable parts of days for the two sets of plants was as follows:

	9 a.m. to 1 p.m.	1 p.m. to 5 p.m.	5 p.m. to 9 a.m.
Plants with old leaves . .	263 cc.	258 cc.	232 cc.
Plants with young leaves	277 cc.	269 cc.	235 cc.

Though for each part of each day the plants with young leaves lost slightly more than those with old leaves, the differences were too small to be significant.

RELATIVE TRANSPIRATION RATE FROM FEW AND MANY LEAVES

Because of the difficulty at times of obtaining plants with equal leaf areas, it was desirable to know whether plants with small leaf surfaces transpired relatively more than did plants with large leaf surfaces. In the first test of this, plants of the Ettersburg 121 variety in 6-inch pots were used. The loss through the leaves over a period from August 5 to 24 in the greenhouse was as follows:

TABLE I—TRANSPIRATION RATE OF ETTERSBURG 121 PLANTS WITH VARYING AMOUNTS OF FOLIAGE

Plant No.	Leaf Area (Sq. Cms.)	Water Loss (Cc.)	Loss per Sq. Cm. (Cc.)
Few-leaf Plants			
1	125.8	554.4	
2	126.3	561.4	
3	127.7	575.8	
Average . . .	126.6	563.9	4.46
Many-leaf Plants			
1	534.0	1197.8	
2	612.1	1229.8	
3	651.3	1210.2	
Average . . .	599.1	1212.6	2.02

In this test the plants with small leaf areas (21 per cent as much as the many-leaf plants) lost over twice the water per unit area as did the plants with large leaf areas. Moreover, the plants in each set were remarkably consistent in the amounts lost.

In order to check the results a second test was made using plants of *Fragaria virginiana* 27 with a series of leaf areas from 50 to 350 sq. cms. These plants had been in the greenhouse under favorable conditions for about 2 months. Plants of about the same size were selected and the leaf areas then reduced to the amounts determined. The number of leaves on the plants was not enough to make shading

a factor. This test continued from September 16 to 29, the plants receiving full sunlight with results as follows:

TABLE II—WATER LOSS FROM *F. virginiana* PLANTS WITH VARYING AMOUNTS OF FOLIAGE

Plant No.	Leaf Area (Sq. Cms.)	Water Loss (Cc.)	Loss per Sq. Cm. (Cc.)
1	50	177.2	3.54
2	125	321.8	2.57
3	200	330.0	1.65
4	275	436.3	1.59
5	350	542.9	1.55

In a third test of transpiration, plants of *F. virginiana* 27 and *F. chiloensis* 13-C were used. These plants had been in the greenhouse under favorable conditions for about 4 months and the leaf area reduced to series from 25 to 350 sq. cms. in extent. In contrast to the second test, these plants were kept in the shade for the entire period of 15 days.

TABLE III—WATER LOSS FROM PLANTS OF TWO SPECIES OF STRAWBERRIES WITH DIFFERENT LEAF AREAS, GROWN IN SHADE

Plant No.	Species	Leaf Area (Sq. Cm.)	Water Loss (Cc.)	Loss per Sq. Cm. (Cc.)
1.....	<i>F. virginiana</i>	25	62.0	2.48
	<i>F. chiloensis</i>	25	54.9	2.20
2.....	<i>F. virginiana</i>	50	90.3	1.81
	<i>F. chiloensis</i>	50	62.0	1.24
3.....	<i>F. virginiana</i>	125	203.4	1.63
	<i>F. chiloensis</i>	125	164.4	1.31
4.....	<i>F. virginiana</i>	200	323.8	1.62
	<i>F. chiloensis</i>	200	260.1	1.30
5.....	<i>F. virginiana</i>	275	380.4	1.39
	<i>F. chiloensis</i>	275	302.5	1.10
6.....	<i>F. virginiana</i>	350	461.6	1.32
	<i>F. chiloensis</i>	350	371.6	1.06

The data in Table III indicate that even in the shade the water loss per sq. cm. is much greater for plants with small leaf surface than for those with much leaf surface. The amounts lost were not as great for plants in the shade as for those in the sun nor were the differences relatively as great for plants having 50 sq. cms. and over of leaf surface.

In these tests it is apparent that, within certain limits at least, the smaller the leaf area the greater the transpiration per unit of leaf surface. If a part of the leaf area is removed, the remaining leaves transpire more water than they otherwise do. Presumably, also, stomata of the leaves remaining on plants where the leaf surface has been reduced are open more of the time and function more effectively in photosynthesis than stomata on many-leaved plants. This response of leaves may have a bearing on the practice of topping the

TABLE IV.—TRANSPIRATION PER 100 SQ. CM. OF FOUR SETS OF 11 VARIETIES AND SPECIES OF STRAWBERRIES FOR 6 TO 12 DAYS

Variety or Species	Set 1		Set 2		Set 3		Set 4		Average	
	Leaf Area (Sq. Cms.)	Loss per 100 Sq. Cm. (Cc.)	Leaf Area (Sq. Cm.)	Loss per 100 Sq. Cm. (Cc.)	Leaf Area (Sq. Cm.)	Loss per 100 Sq. Cm. (Cc.)	Leaf Area (Sq. Cm.)	Loss per 100 Sq. Cm. (Cc.)	Leaf Area (Sq. Cm.)	Loss per 100 Sq. Cm. (Cc.)
<i>F. chiloensis</i> 5-C.....	85	15.58	65	13.37	75	8.06	75	6.00	75	10.76
<i>F. chiloensis</i> 13-C.....	85	11.69	65	14.52	75	7.41	100	6.00	81	9.91
<i>F. cuneifolia</i> 14.....	85	12.57	65	10.15	75	6.75	100	5.31	81	8.70
O. S. C. 113.....	140	9.87	140	9.11	135	6.90	150	5.08	141	7.74
O. S. C. 192.....	140	9.24	140	7.23	200	5.97	150	3.79	156	6.56
O. S. C. 118.....	170	10.66	200	6.69	125	7.90	150	4.83	161	7.52
Ettersburg 121.....	170	7.61	140	7.99	135	8.61	100	5.25	136	7.37
<i>F. virginiana</i> 27.....	170	8.86	140	8.44	200	5.94	150	5.67	165	7.23
O. S. C. 186.....	215	7.88	200	7.31	245	6.05	150	3.83	202	6.27
Marshall.....	215	5.81	200	5.50	245	5.98	150	4.04	202	5.33
Corvallis.....	215	8.34	140	6.38	200	6.69	150	5.16	176	6.64

plants after the harvest period, for a relatively small amount of new foliage may be as efficient as a much larger amount of old foliage.

RELATIVE TRANSPIRATION OF SPECIES AND VARIETIES

Four sets of plants were used to obtain data on the relative water loss of 11 varieties and species. These were vigorous greenhouse plants in 5-inch pots sealed with paraffin. The original leaf areas being unequal were reduced as shown in Table IV. Comparisons may be made only between lots having approximately similar leaf areas.

From the data in Table IV, it is apparent that varieties and species differ considerably in transpiration per unit area. Marshall had the lowest average rate of transpiration, though under the conditions for Set 4, varieties O. S. C. 192 and 186 had slightly lower rates. *F. chiloensis* 5-C on the average transpired slightly more than did *F. chiloensis* 13-C and both *F. chiloensis* selections more than did *F. cuneifolia* 14.

RELATIVE RATE OF WILTING

It seemed worth while to compare the length of time it took previously well-watered plants of different varieties and species to wilt and die under indoor and outdoor conditions. Six potted plants of each sort sealed with paraffin were used, three being placed in the greenhouse and three outside. The leaf area of all the plants was recorded and the test began August 25 and continued until all plants died.

Generally speaking, the different sorts did not show survival values according to their leaf areas. Thus, plants of the two selections of *F. chiloensis* had the smallest leaves and leaf area and lived longest, averaging 52.3 and 50.6 days. However, plants of *F. cuneifolia* 14 which had as small a leaf area as one lot of *F. chiloensis* lived only 32.4 days and plants of O. S. C. 186 (Marshall x *F. chiloensis*) which had over twice the leaf area of these three species lived an average of 50.2 days. The Corvallis plants with a smaller leaf area than the Marshall lived an average of 21.9 days and the Marshall plants an average of 43.7 days.

It seems probable that the conditions of growth previous to the start of wilting affect the several varieties differently and that an understanding of the "conditioning" processes is essential to critical tests to determine drought resistance of selections in breeding work. For example, *F. chiloensis* and *F. cuneifolia* have extraordinary survival values under some drought conditions but apparently not under others. The Corvallis withstood drought in the field in June, 1931, much better than did Marshall and Ettersburg 121, yet in this test died first.

RELATIVE WATER LOSS DURING DAY AND NIGHT

In one series a record of the water loss of six plants each of 11 varieties and species for the day and night periods was obtained for 9 days (August 25 to Sept. 4). For plants with an average of 140 sq. cms. of leaf surface the loss at night (7:00 p.m. to 7:00 a.m.) represented 15 per cent of the total and the day loss 85 per cent. There seemed to be no species or variety that lost significantly more at night but less during the day, than did other sorts.

In another series using four greenhouse plants each of the 11 varieties and species with an average of 143 sq. cms. of leaf surface, the water loss during 9½ days was 37 per cent for the 4 hours 9:00 a.m. to 1:00 p.m., 35 per cent for the 4 hours 1:00 to 5:00 p.m. and 28 per cent for the 16 hours 5:00 p.m. to 9:00 a.m. All sorts lost approximately at the same relative rate for the different parts of the day.

WATER ABSORPTION BY LEAVES

The beach strawberry, *F. chiloensis*, is found only in a narrow strip on the coast of the Pacific Ocean, rarely being found more than a few hundred feet from the water. On the Oregon coast fogs are frequent at certain seasons, and it was considered possible that besides reducing evaporation some absorption through strawberry leaves might be possible. In the first test, a vigorous potted plant of Ettersburg 121 was sealed with paraffin and allowed to wilt. It was then turned bottom up so that the entire leaf surface was in the water from August 22 to 25. The leaves became turgid and the plant showed a gain in weight of 28 grams for this period.

A second test using a plant of O. S. C. 186 (Marshall x *F. chiloensis*) was made September 1 to 8. After wilting, the plant was turned bottom up with the leaves in water. Again the leaves became turgid and a gain of 29.1 grams were recorded.

A third test using three plants each of both Marshall and *F. chiloensis* 13-C, October 31 to November 6. Leaf area measurements were taken and exactly the same leaf areas (760 sq. cms.) used for each sort. The plants were slightly wilted before the leaves were submerged. After 3 days, the leaves had become turgid and the plants had gained as follows:

Marshall—6.2 gms., 4.5 gms., and 2.8 gms.; total of 13.5 gms.

F. chiloensis 13-C—4.9 gms., 4.0 gms., and 2.5 gms.; total of 11.4 gms. The plants were then taken out of the water for a day and when badly wilted were again submerged. After 2 days they had gained as follows:

Marshall—4.5 gms., 4.2 gms., and 2.8 gms.; total of 11.5 gms.

F. chiloensis 13-C—4.8 gms., 4.5 gms., and 2.5 gms.; total of 11.8 gms. There was evidence of absorption by the leaves under the conditions of this test and of about the same value for both kinds. Though the amount of absorption was not great, it was sufficient to enable the leaves to recover turgidity.

Effect of Fertilizers on Firmness and Flavor of Strawberries in North Carolina¹

By GEO. M. DARROW, *U. S. Dept. of Agriculture, Washington, D. C.*

PRESSURE tests to measure the effect of fertilizers on firmness of strawberries were made at Willard, N. C., in 1928 and 1931. A pressure tester designed by A. G. Galloway was used in 1928 and a Chatillon berry tester of the type used by Clark (1) in 1931. Both testers are based on the pressure required to force a blunt plunger into the berries to a depth of one-eighth inch, the pressure being read on a dial in units on the Galloway tester and on a scale in grams on the Chatillon tester. The berries were always held in the same position; the plunger was forced into the berry on the shoulder about one-third of the distance from the calyx to the apical end and forced in at a uniform rate.

In 1928, 40 berries were tested from each plot on each of four dates, the tests being made on May 4, 5, 10, and 15. Care was used to select berries of uniform size, shape, and maturity. The fertilizers were broadcast on the beds at the rates given below on September 28, 1927. Table I shows the average pressures.

TABLE I—PRESSURE TEST RESULTS ON BERRIES FROM FERTILIZER PLOTS, 1928, EXPRESSED AS PERCENTAGES OF THE CONTROL

Plot No.	Treatment	Amount (Lbs.)	Per cent Pressure as Compared with Control (Per cent)
1	Tankage (9.0% N).....	500	2.0
2	Nitrate of soda (14.8% N).....	500	5.9
3	Superphosphate.....	2000	12.9
4	Nitrate of soda (as in 2) and superphosphate (as in 3)	2500	8.9
5	No fertilizer (control).....		
6	Sulfate of potash.....	500	5.9
7	Muriate of potash (50% K ₂ O).....	500	1.0
8	Nitrate of soda (as in 2) and muriate of potash (as in 7).....	1000	16.8
9	Superphosphate (3) and muriate of potash (as in 7)	2500	10.9
10	Nitrate of soda (2) and superphosphate (as in 3) muriate of potash (as in 7).....	3000	8.9
11	6(P) — 3(N) — 5(K) (complete).....	1500	0.0

Though the fruit of all plots except plot 11 (complete fertilizer) showed greater firmness than the control, the differences were neither consistent nor significant. Thus, the muriate of potash plot (plot 7) gave next to the lowest while the nitrate of soda plus muriate of potash plot (plot 8) gave the highest pressure test. As a whole, these

¹This paper records some phases of coöperative investigations on strawberries at the Coastal Plain Station in which the Bureau of Plant Industry and the No. Car. Dept. of Agr. are coöperating.

TABLE II—PRESSURE TESTS OF SMALL AND MEDIUM SIZE BERRIES FROM FERTILIZER PLOTS—AVERAGE OF 8 PICKINGS, APRIL 21 TO MAY 15, 1931
30 BERRIES PER PLOT FOR EACH PICKING

Plot	Pressure (Grams)		Firmness as Compared with Control (Per cent)		
	Small	Medium	Average	Small	Medium
0(P) — 4(N) — 0(K)					
2.....	357.1	339.1	—2.7		
2a.....	365.9	334.7	—2.1		
2b.....	356.9	340.4	—2.6		
Average.....	360.0	338.1	—2.6	+0.6	—5.5
8(P) — 0(N) — 0(K)					
3.....	385.4	358.9	+4.0		
3a.....	369.1	350.8	+0.6		
3b.....	373.7	349.8	+1.1		
Average.....	376.1	353.2	+1.9	+5.1	—1.3
0(P) — 0(N) — 6(K)					
5.....	392.5	365.4	+5.9		
5a.....	372.4	348.1	+0.7		
5b.....	382.1	343.1	+1.1		
Average.....	382.3	352.2	+2.1	+6.8	—1.6
8(P) — 4(N) — 6(K)					
7.....	349.3	338.0	—3.9		
7a.....	360.2	340.9	—2.0		
7b.....	351.8	344.4	—2.7		
Average.....	353.8	341.1	—2.9	—1.1	—4.7
0(P) — 4(N) — 0(K)					
8.....	382.0	367.5	+4.7		
8a.....	391.6	344.9	+2.8		
8b.....	367.9	345.6	—0.3		
Average.....	380.5	352.7	+2.2	+6.3	—1.4
8(P) — 4(N) — 0(K)					
9.....	350.6	354.7	—1.4		
9a.....	371.1	346.8	+0.3		
9b.....	359.8	332.3	—3.3		
Average.....	360.5	344.6	—1.4	+0.8	—3.7
0(P) — 4(N) — 6(K)					
10.....	379.8	352.8	+2.4		
10a.....	371.6	352.8	+1.2		
10b.....	358.8	331.7	—3.5		
Average.....	370.1	345.8	0.0	+3.4	—3.3
0(P) — 4(N) — 0(K)					
12.....	367.5	358.5	+1.5		
12b.....	339.2	329.3	—6.6		
Average.....	353.4	343.9	—2.5	—1.2	—4.9
Control—No Fertilizer					
X.....	356.7	358.8	—	—0.3	+0.3
Average of all.....	365.9	347.8	—0.3	+2.3	—2.8

Note: The small berries were 5.2 per cent firmer than medium sized ones.

tests showed no significant effects of fertilizers on firmness. Practically all fertilized plots showed slightly increased firmness as compared to the control. The single control plot, however, may not represent a true index of the firmness of non-fertilized berries.

In 1931, pressure tests were made with the Chatillon tester at each of eight pickings from April 21 to May 15, 30 berries from each plot being used at each picking. Before testing, the berries were carefully graded into small and medium sizes, too few large sized berries being available for testing. The fertilizer was applied twice, half in September, 1930 and the rest in January, 1931. The fertilizer was based on an 9(P)-4(N)-6(K) application at the rate of 1500 pounds per acre. Triplicate plots were used, 2a and 2b receiving the same applications as plot 2. The nitrogen used on plots 12 and 12b was derived from organic sources only, one-half from tankage and one-half from cottonseed meal; that used on plots 8, 8a and 8b from inorganic sources, one-half from nitrate of soda and one-half from sulfate of ammonium, and that used on plots 2, 2a and 2b from all four of the above sources in equal proportions. The phosphate was derived from superphosphate and the potassium from muriate of potash. Table II summarizes the results.

An inspection of Table II indicates that berries from the nitrogen plots, (8, 8a and 8b) where the nitrogen was derived from nitrate of soda and sulfate of ammonia, averaged the firmest (2.2 per cent above the control), while those from complete fertilizer plots (7, 7a and 7b) averaged the softest. In general, where leaf growth was least (plots 3, 3a, 3b, 5, 5a, 5b, and 8, 8a, 8b) the berries were firmest and where leaf growth was greatest (plots 2, 2a, 2b, 7, 7a, 7b, 9, 9a, 9b, and 12, 12b) the berries were softest. There was relatively little difference in firmness of berry between the different fertilizer plots.

Averaging all plots receiving nitrogen fertilizer, either alone or in combination with P and K gives an average of 1.2 per cent below the check in firmness. Similarly averaging all plots receiving P gives an average of 0.8 per cent below the check, and the K plots were 0.3 per cent below the check. These differences obtained by using berries of similar size from the different plots are obviously too slight to be significant.

Though there was little evidence that fertilizers made berries firmer, or softer, the difference (5.2 per cent) in pressure tests of the small and medium sized berries is consistent and sufficient to be significant. Small berries have a higher dry weight than large ones² and the greater dry weight of the small berries seems to be correlated with higher pressure tests than for large berries.

The plots to which nitrogen has been applied have in previous years produced much larger berries than those to which no nitrogen had been applied. In 1931 but few counts were made. In 1930, however, counts of 11 to 14 quarts from each plot from which the records in

²Unpublished data of writer.

Table II were obtained gave an average of 13 per cent larger berries from nitrogen plots than from those not receiving nitrogen. Observations and some counts made in other years have confirmed this result. The larger size of berries from nitrogen plots seems to have been produced by greater swelling of the berries. Since large berries tend to be softer than small ones, it would be expected that the larger berries from the nitrogen plots would be softer than those from the no-nitrogen plots.

While the pressure testers here used give a satisfactory mechanical reading of the firmness of the berry, other factors also enter into the determination of carrying and storage quality. Toughness of skin and tendency to shrivel are especially important. Consequently, holding tests of berries from the various fertilizer plots have been made during each of the 4 years since 1928 and shipping tests during 2 of the years in which fertilizer effects have been studied in North Carolina. These tests also have shown no effect of fertilizers on storage or carrying quality. The tests have indicated, however, that in some seasons fertilizers may have indirect effects on shipping quality in that the nitrogen may increase leaf size and number, and in turn the larger and greater number of leaves tend to increase the amount of rot in the field and in transit. A fuller report of this is being published elsewhere.

In the fertilizer plots at Willard the Missionary variety was used in 1928 and 1929. In 1928, no consistent differences in flavor due to fertilizers were noted. In 1929, berries were tested for flavor on May 4 and, in the opinion of the writer, the differences were very apparent. Berries from plots receiving both muriate and sulfate of potash were sour and lacking in flavor. Berries from the plots receiving sulfate of potash plus nitrogen (tankage and nitrate of soda) were only slightly less sour and were also lacking in flavor. Berries from the superphosphate plots were sweeter and better in flavor than from the above mentioned ones while those from the plots receiving superphosphate plus nitrogen (tankage plus nitrate of soda) were much the sweetest and finest in flavor. Berries from the control and from the nitrogen (tankage) plots were more sour than those from the superphosphate plots. Berries from the duplicate plots had similar rank in flavor. It is noteworthy also that plots with both sparse and heavy leaf growth produced poor or fine flavored berries according as potash or superphosphate was applied.

The reason for the apparent differences in the development of flavor in 1928 and in 1929 is not evident. Both seasons were cool and wet but that of 1928 was nearly 3 weeks later than that of 1929. The temperatures just before the tests were made were above average but were higher in 1928 than in 1929. Leaf growth was much less in 1929 than in 1928.

In 1930, with the Blakemore variety, differences in flavor could be detected at times during the season, though not always. In general, the fruit from the phosphorus and nitrogen plots seemed to be the

best flavored and that from the potassium plots the poorest flavored. Preserves were made in the National Preservers Association Research Laboratory in Washington, from fruit from the different plots. Specialists from that laboratory reported that preserves from the plots receiving nitrogen, nitrogen plus phosphorus, and phosphorus were markedly superior to preserves made from berries from the plots receiving potassium and potassium plus nitrogen.

In 1931 no consistent differences in effects of fertilizer on flavor were obtained.

The results in 1929 corroborate the findings of Vercier (2) on the effect of fertilizers on the flavor of strawberries. Vercier scored berries from fertilizer plots for flavor. With berries from a control plot scoring 80.0 and described as having a typical strawberry flavor, berries from a plot to which slag and sulfate of potash but no nitrogen were applied scored 60.0 and were described as lacking flavor and not so sweet. Berries from a complete fertilizer plot were scored 63.0 but those from a slag and nitrogen plot with no potash were scored 93.5 and were described as having very fine flavor. Those from a sulfate of potash and nitrogen plot scored 75.5.

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The Effect of Fertilizers on the Handling Qualities and Chemical Analyses of Strawberries and Tomatoes

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A. HANDLING QUALITIES

PRACTICALLY all of the strawberries grown in Oklahoma are sold in carload lots and are shipped to cities as far north as St. Paul and east to Pittsburg. They must be in good condition to stand this long shipment. Besides the distance, there are several other conditions which make the problem of the firmness of the fruit important. At harvest time the temperature is high with frequent rains. Many of the berries are grown on new land which produces a heavy foliage.

The development of a green-wrap tomato industry and a question of quality as well as yield for the tomato canneries of the state seemed to justify the experiment station in starting work on this phase of the problem. It seemed wise that a laboratory study be made of the structure as well as the chemistry of the fruits grown under the various treatments.

Claims have been made that fertilizers high in nitrogen will cause soft fruit while others claim that potash or a combination of these will produce a firmer fruit. In order to study this problem, work was started in which strawberry plants were grown in especially constructed concrete beds. A slope of 1 inch to 6 feet allowed sufficient drainage for each bed while the 4-inch slope in the 70 feet with drain tile prevented any fertilizer that leached out from reaching the adjoining plot.

The general growth of the plants seemed to indicate that there was no effect from one plot on another. The soil was made up of $\frac{1}{2}$ river-washed sand and $\frac{1}{2}$ fine sand known as "blow sand," both low in fertility.

The fertilizers were mixed and worked into the soil by cultivating it 2 inches deep. After 3 days, on March 10, the plants were set out, using 49 uniform pot-grown plants to each bed. No blossoms were allowed to form the first year. No plot without nitrogen being applied in the form of commercial fertilizer produced enough berries for a test the first year. All those receiving nitrogen did. In December a heavy mulch of prairie hay was applied. The fertilizer treatments per plot were as follows: 1000 lbs. per acre each of 10-5-5, 10-5-0, 10-5-10, 10-5-3, 0-5-3, check, 5-5-5, MnSO_4 , 10-0-5, 10-3-5, 10-5-5, 10-10-10, the order being N P K.

These plants were watered following the picking. Pressure tests were made on the shoulder of the berry, using 25 berries from each bed and six lots taken at different times. This gave 150 pressure tests

TABLE I—AVERAGE PRESSURE OF EACH PICKING OF STRAWBERRIES FROM FERTILIZER TREATMENTS AT STILLWATER

Date Tested	I 10-5-5	II 10-5-0	III 10-5-10	IV 10-5-3	V 0-5-5	VI 0-0-0	VII 5-5-5	VIII MnSO ₄	IX 0-0-0	X 10-0-5	XI 10-3-5	XII 10-5-5	XIII 10-10-10
5/29	63.8	63.4	60.4	—	65.8	69.8	—	72.1	72.8	61.8	67.4	64.9	67.8
6/2.	87.6	73.3	73	70	83.8	83	79.4	98.6	95	24.4	69	75.4	73.5
6/5	66.6	67.9	71	72	76.6	82.6	72.8	—	—	78.6	79.6	82.3	69
6/6	49.2	51	52	53.2	57.6	65	59.2	73	—	46.2	53.4	52.2	50.2
6/8	53.2	50.5	62.4	58.4	71.2	65.4	59.8	72.8	—	55.8	54	50.8	48.8
6/11	56.6	52.2	49	49.4	55	48.2	62	—	—	44.4	46.2	37	40
Total average.....	62.1	59.8	61.3	62.4	68.4	88.9	62.8	79.6	83.9	61.8	61.6	60.6	58.2

for each treatment. The pressure tester is one used for testing sweet corn and is made by the L. S. Starrett Company, Athol, Mass. A plunger of 3.516 mm. diameter was used. The same tests were made on berries grown under field conditions in triplicate plots, each 40 x 50 feet. The soil is a sandy loam low in humus.

TABLE II—NUMBER AND WEIGHT OF BERRIES FROM CONCRETE BEDS AT STILLWATER

Plot No.	Treatment	Total No. Berries	Total Weight (Grams)	Average Weight per Berry (Grams)
I.....	10-5-5	849	4943.2	5.82
II.....	10-5-0	809	5460.67	6.75
III.....	10-5-10	761	5172.98	6.8
IV.....	10-5-3	681	5184.8	7.61
V.....	0-5-3	477	3034.1	6.36
VI.....	0-0-0	567	3354.76	5.93
VII.....	5-5-5	704	4647.02	6.08
VIII.....	MnSO ₄	368	3544.4	6.88
IX.....	0-0-0	—	—	—
X.....	10-0-5	595	4766.5	6.33
XI.....	10-3-5	592	3970.7	6.707
XII.....	10-5-5	610	4254.1	7
XIII.....	10-10-10	693	4538.2	6.54

The dry weather of 1929 and 1930 made the yields in the field vary somewhat with the amount of nitrogen applied. All the applications were figured at 1,000 pounds to the acre, half of which was applied in September and the other half in March of the following spring.

There was one plot in the field in which a fertilizer of 15-5-3 was used. In all cases under field conditions where the application of nitrogen was high, fewer plants came through the dry season, with a smaller yield per plot. This holds even for tomatoes which were grown under field conditions near the strawberries.

Berries were held for 5 days in a storage at 40 degrees F. and then allowed to stand in a warm room 2 days. It was found that every berry that showed decay had been bruised in picking. The decay started on the shoulder of the berry. In another test, a number of berries had been washed with a spray of water on one side. The fruits were then exposed to direct sunlight. The side of the fruit that was washed shriveled in 3 hours while the berries which were not washed did not show this drying. Little difference was found in the berries from the different fertilizer treatments as shown in the table of pressure tests and the same is true in the shipping of the tomatoes.

Tables I to V show that out of seven shipments of tomatoes in which the 6-basket carrier was used, those from the check plot shipped best, but that the treatment 10-3-5 was next best. This is only 2 years' work, both years of which were very dry, and so no conclusions are drawn.

With the strawberry, it seems that the humidity at or just previous to picking has much to do with the firmness of the berry. From the

TABLE III—AVERAGE PRESSURE OF EACH PICKING OF STRAWBERRIES GROWN UNDER FIELD CONDITIONS AT PERKINS

Date Tested	Series and Plot Numbers with Fertilizer Treatment											
	I-1 10-5-5	I-2 10-5-0	I-3 10-5-10	I-4 10-5-3	II-1 0-5-5	II-2 0-0-0	II-3 MnSO ₄	II-4 10-5-5	III-1 10-0-5	III-2 10-3-5	III-3 5-5-5	III-4 10-10-10
6/1	80.4	59.6	78.4	63	77.8	72.8	71.8	80.2	74.6	75	66.4	60.6
6/4	76.2	79.4	71.2	70.8	75	75.6	89.2	73.2	64.4	76	76.8	78.8
6/9	40.6	47.4	49.2	51.6	49.8	51	48	51	52.2	68	52.6	61.4
Totals	65.7	62.1	66.2	61.6	67.5	66.4	69.6	68.3	63.7	68	65.2	69.6

amount of injury that occurs from careless picking and handling, it would seem that a mechanical picker which would cut the pedicel of the berry might be desirable. The amount of rainfall during the harvesting may so affect the firmness of the fruit that the grower will pick the fruit less mature for distant shipment. It seems, from our work, that the fruit in the latter part of the season is softer than during the early or mid-season.

TABLE IV—RESULTS OF FERTILIZERS ON THE HANDLING QUALITIES OF TOMATOES JULY 29, TO AUGUST 19, 1931, 7 SHIPMENTS

Fertilizer Treatment	Total Firm Fruit	Total Slightly Soft Fruit	Total Soft Fruit	Total Bruised Fruit	Total Broken Fruit	Total Decayed Fruit	Total Fruit Used
0-5-5.....	29	27	33	24	14	25	124
10-5-10.....	19	28	41	37	9	25	135
10-10-10.....	21	27	47	32	7	30	131
10-5-5 (I-1).....	23	25	40	35	12	28	133
10-0-5.....	30	16	43	23	11	29	128
10-3-5.....	35	30	18	27	13	27	130
15-5-5.....	30	17	32	22	5	25	128
Check.....	41	27	29	27	12	11	129
Mn SO ₄	29	23	35	34	13	19	130
10-5-0.....	25	40	30	32	15	19	136
10-5-15.....	29	32	62	35	14	27	146
10-5-5 (III-3).....	28	21	34	33	11	19	129

TABLE V—YIELD OF BONNY BEST TOMATOES FROM FERTILIZER TEST AT PERKINS (CALCULATED ON BASIS OF 25 VINES PER PLOT)

Total Number and Weight of All Three Plots of Like Treatment				
Series No.	Plot No.	Treatment	Total No. Fruits	Total Weight Fruit
I.....	1	10-5-5	1423	237.2
II.....	1	0-5-5	1569	267.4
III.....	1	10-0-5	982	150.4
I.....	2	10-5-0	1454	215.5
II.....	2	0-0-0	1256	201.8
III.....	2	10-3-5	1414	202.6
I.....	3	10-5-10	1764	246.8
II.....	3	MnSO ₄	1216	203.6
III.....	3	10-5-5	1487	235.2
I.....	4	10-5-15	1727	252.5
II.....	4	15-5-5	1528	231.6
III.....	4	10-10-10	1892	280.2

B. CHEMICAL ANALYSES

The chemical analyses of strawberries and tomatoes herein reported are only the beginning of this phase of the work and should not be considered as final. In this work the conventional methods were used in securing the figures for water and acidity percentages. The Youden quinhydrone indicator set was used in securing the pH figures. For the determination of sugars, samples were preserved in alcohol and estimations run on the extract using the Shaffer-Hart-

TABLE VI—CHEMICAL ANALYSES OF STRAWBERRIES SHOWING THE EFFECT OF VARIOUS FERTILIZERS APPLIED IN THE FIELD

Fert.	Acidity	pH	Percentage Fresh Weight								
			Water	Solids	Red. Sug.	T. Sug.	Acid Hydrol.	Residue	Pectin	Proto-Pectin	Total Pectin
10-5-5.....	8.7	3.71	90.31	9.69	3.76	3.90	.49	1.73	.223	.148	.371
10-5-0.....	9.2	3.63	90.13	9.87	3.70	3.87	.44	1.76	.229	—	—
10-5-10.....	10.5	3.67	91.15	8.85	3.16	3.26	.46	1.63	.223	.128	.351
10-5-3.....	9.6	3.63	90.83	9.17	3.68	3.76	.54	1.51	.282	.106	.388
0-5-5.....	10.0	3.54	89.97	10.03	4.28	4.37	.48	1.77	.251	.158	.409
0-0-0.....	9.5	3.66	89.75	10.25	4.31	4.44	.54	1.58	.257	.163	.420
MnSO ₄	10.5	3.54	90.70	9.30	4.05	4.41	.50	1.58	.228	.162	.390
15-5-5.....	11.3	3.62	90.87	9.13	3.33	3.38	.55	1.63	.231	.159	.390
10-0-5.....	10.5	3.60	90.68	9.32	3.28	3.87	.58	1.76	.283	.119	.402
10-3-5.....	9.3	3.71	91.08	8.92	3.73	3.66	.52	1.62	.271	.152	.423
5-3-5.....	10.1	3.68	90.55	9.45	4.10	4.07	.47	1.66	.290	.122	.412
10-10-10.....	10.7	3.60	91.66	8.34	3.43	3.66	.49	1.20	.293	.152	.445

man procedure. Pectin constituents were estimated essentially as done by Appleman and Conrad (1).

In Table VI are shown the analyses of strawberries grown in the field. Analyses of samples grown in the concrete beds are not included in order to save space. Except in the case of acidity and total pectin, which are slightly higher, the two series of analyses are quite similar.

TABLE VII—CHEMICAL ANALYSES OF TOMATOES SHOWING THE EFFECT OF VARIOUS FERTILIZER TREATMENTS APPLIED IN FIELD. (1930 AND 1931)

Fert.	Acidity	Percentages of Fresh Weight					
		Water	Solids	Red. Sug.	Acid Hydrol.	Residue	Pectin
10-5-5..	10.55	92.84	7.16	2.77	.342	.834	.105
10-3-5..	11.52	93.54	6.96	2.74	.379	.819	.088
10-10-10	12.10	92.58	7.42	2.66	.376	.849	.068
10-5-0..	11.40	93.01	6.99	2.80	.362	.872	.086
15-5-5..	11.00	93.05	6.95	2.88	.317	.775	.124
10-5-10.	10.70	92.95	7.15	2.89	.363	.796	.104
10-5-15.	12.10	92.84	7.16	2.82	.371	.819	.120
10-0-5..	10.08	92.94	7.06	2.70	.348	.834	.114
Check...	9.35	93.02	6.98	2.77	.331	.810	.102
0-5-5...	12.38	92.62	7.38	2.78	.350	.790	.102
MnSO ₄ ..	9.75	93.28	6.72	2.78	.323	.885	.114

While admitting that probably the variations in chemical composition of berries harvested from any one plot at different times are greater than the differences due to fertilizer applications as shown by Kimbrough (2), we cannot overlook the fact that these berries as sampled were picked at nearly comparable stages of maturity, which should overcome most of this difficulty. In attempting to correlate these data with the results of pressure tests given in Part A, we find only one significant fact, namely, that those berries which showed the highest test were invariably highest in total pectin. However, the total pectin percentages cannot be said to vary in any manner corresponding to the fertilizer treatments as shown in the table, for the two highest percentages are from the 10-10-10 and check plots. Perhaps data from future years will show a greater correlation.

Our work with tomatoes was quite like that with strawberries, except that in sampling the fruit we could select ample material from all plots at one time of about the same degree of ripeness, thus removing most questions as to uniformity of samples. Table VII is a compilation of 2 years' work. In this table, total pectin and protopectin figures are omitted, since the 1930 figures for these compounds are not available. For 1931 these figures are similar in range to the pectin figures. It is interesting to note the absence of any disaccharides in tomatoes, a fact confirmed by two years' findings.

In attempting to correlate these figures with the shipping data given in Part A, we find very little correlation possible. In examining the carbohydrate analyses, we at once see not a difference but a re-

markable similarity in the figures, so much so in fact that it becomes a point for comment. Such a similarity is shown in each year's work. Perhaps the best explanation lies in the scant rainfall each year at the time when the fruit was maturing. In examining the pectin percentages we find marked differences, but these differences, as a rule, do not correspond to the results of the shipping tests. What little evidence of correlation appears seems to indicate that the lower content of pectic materials is found in samples which ship best. More work will be necessary, however, before any final statements may be made dealing with this factor.

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Respiration Studies with Lettuce

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MAGNESS and Ballard (4) studying pears, Burroughs (1) employing apples, and Overholser, Hardy and Locklin (7) with strawberries, have indicated that respiration intensity is to some extent, a measure of the degree of maturity. Overholser (1930) reported that the type of container may modify the atmosphere surrounding the fruits or vegetables.

MATERIALS AND METHODS

The lettuce for the respiration studies was obtained from two sources, *i.e.*, the local stores at Pullman, Washington, and directly from commercial fields at Puyallup, Washington. The material from the first source was comparable to lettuce as purchased by consumers, while that from the second source was comparable to freshly harvested lettuce.

Ten-inch desiccators fitted with rubber stoppers and stop-cocks were used as respiration chambers. Each jar held one large or two small heads of lettuce. Constant temperatures were maintained and the gas samples were analyzed by means of an Orsat apparatus.

To obtain gas samples from between the leaves and from the inter-cellular spaces, the heads were placed in the jars and the lids securely affixed. By means of a two-holed rubber stopper, one tube extended to the bottom of the jar and the other, to just within the jar. The jar was inverted over a ring stand and a saturated salt solution allowed to run in until the desiccator was filled. The tube extending to the bottom was then closed and suction applied until all the salt solution was withdrawn. The solution was then allowed to run in again until the pressure within was equalized with the atmospheric pressure without. The gas that had collected in the jar was then withdrawn and analyzed.

To obtain a sample of the gas from between the leaves, a desiccator was filled with water and inverted over a large tub of water. The head of lettuce was then plunged into the water and under the desiccator. As the leaves were stripped off, the gas collected in the jar and was then drawn off and analyzed.

PRESENTATION OF DATA

Maturity: The rate of respiration of mature and immature lettuce from commercial fields was compared. The immature lettuce was small, soft, and not sufficiently mature for commercial harvest. The

¹The data reported were obtained while the writer was engaged in graduate work at the State College of Washington. The many helpful suggestions and criticisms received from Dr. E. L. Overholser and other members of the faculty are gratefully acknowledged.

data are as follows: For the first 6 hours the immature lot respired 92.37 mgms. of carbon dioxide per kilo per hour, the next six hours 53.29 mgms. and for the last 12 hours, 36.10 mgms. The mature lot respired 65.27 mgms. of carbon dioxide per kilo per hour for the first 6 hours, 43.93 mgms, for the next 6 hours, and 34.11 mgms. for the last 12 hours. The respiration ratio for the immature lot was .736 for the first 6 hours, .571 for the next 6 hours and .687 for the last 12 hours. For the mature lot .95 for the first 6 hours, .794 for the next 6 hours, and .842 for the last 12 hours.

Discarding the first period as the period necessary to reach equilibrium, the immature lot was still higher in respiration intensity than the mature. In the last 12 hours, however, the respiration rate was nearly the same in both lots. The mature heads more nearly approached unity when comparing the respiration ratios.

Temperature: Three lots of lettuce were subjected to temperatures of 0 C., 4.4 C., and 25 degrees C. The 0 degrees C., was maintained in a cold storage room, the 4.4 degrees C., in the greenhouse basement, and the 25 degrees C. in a constant temperature chamber. The lettuce was from a local store, the weights of the individual heads being approximately the same. A check on the loss in weight was also made in conjunction with the respiration studies. The results were as follows: At 25 degrees C. for 48.61 hours in storage the respiration rate was 54.83 mgms. of carbon dioxide per kilo per hour with a respiration ratio of .917 and a 6.33 per cent loss in weight. At 4.4 degrees C. for 60.25 hours in storage the respiration rate was 12.13 mgms. with a respiration ratio of .881 and a 1.28 per cent loss in weight. At 0 degrees C. for 62.95 hours in storage the respiration rate was 6.51 mgms. with a respiration rate of .842 and a 1.21 per cent loss in weight.

The data show that the respiration rate at 4.4 degrees C. increased about 100 per cent over that at 0 degrees C., and at 25 degrees C. the increase was 400 per cent over that at 4.4 degrees C. The increases shown correspond to that found by Gore (3) that for every 10 degrees C. rise in temperature the respiration rate increases 2.376 times. The data also indicate that the higher the temperature the nearer to unity becomes the respiration ratio.

At the two lower temperatures the loss in weight is nearly equal, but at the higher temperature the loss is about five times greater.

Removal of outer leaves: Locally-purchased lettuce of uniform size and weight was used. The respiration intensity of lettuce heads with the outside leaves attached was compared with lettuce having the outside leaves removed. The results were as follows: The heads with the outside leaves removed with a storage test period of 24.68 hours had a respiration rate of 41.85 mgms. of carbon dioxide per kilo per hour. The respiration ratio was .831. The heads with the outside leaves intact with a storage period of 24.6 hours had a respiration rate of 59.57 mgms. and a respiration ratio of .938.

The data show that the heads having the mature outside leaves intact respired more rapidly. The gain in respiration intensity of the intact lettuce head resulted from the outside leaves which had reached a more advanced stage of maturity.

At the conclusion of the tests the heads with the outside leaves attached showed considerable wilting, and slime mold, while the heads with outside leaves removed showed only slight wilting. The centers of both lots were in good condition.

TABLE I—THE INFLUENCE OF CARBON DIOXIDE UPON RESPIRATION INTENSITY

Length of Test (Hours)	Mgms. CO ₂ produced per 1000 grams Lettuce per Hour			Per cent CO ₂ Surrounding Heads of Lettuce		
	Stopcock Closed	Half Open	Open	Stopcock Closed	Half Open	Open
65	35.46	39.27	34.38	8.07	6.32	6.85
112	28.75	23.52	25.00	12.22	9.02	11.15
207	13.71	11.10	10.16	17.05	11.50	14.22
255	10.00	12.43	8.29	18.67	12.97	15.52

Composition of atmosphere: Thornton (9), and Willaman and Beaumont (10), have shown that carbon dioxide has a retarding effect on respiration and tends to keep samples longer than check samples in the open air. Three lots of lettuce were stored in desiccators to test the accumulating effect of carbon dioxide on length of storage period. The first lot was stored in jars completely closed, and only opened to withdraw gas samples for analyses. The second lot was put into jars with the stopcocks one-half open, and the third lot with the stopcocks completely open. Each time an analysis was made only enough air was admitted to equalize the pressure in the jar with the air pressure. Table I gives the results.

In the jars with the stopcocks completely closed the heads showed browning of the outer leaves after 207 hours and after 255 hours showed considerable browning and mold. The heart leaves showed a brown specking typical of suboxidation as described by Stewart and Mix (1917) and Nelson (1926). In the two sets of respiration chambers with the stopcocks partly and completely open, the outer leaves did not show as much breakdown as did those in the closed chambers. The heart leaves, however, showed some specking. All lots were beyond any further use due to breakdown.

The data indicate that an increase in the percentage of carbon dioxide surrounding the lettuce tended to reduce the further production of carbon dioxide.

Tipburn: One of the greatest sources of loss to the lettuce grower is through tipburn. Some lots of lettuce were obtained from a tipburn plot and the respiration intensity compared with commercial lots directly from the fields. An additional lot was stored in a cellar at 15.6 degrees C. for a definite period of time before being tested. All heads were sound, hard, and mature. The results were as follows: In the tipburn plot with no previous storage the rate was 81.85

mgms. for the first 6 hours, 52.02 mgms. for the next 12 hours, and 52.72 mgms. for the last 6 hours. For the commercial plot the rate was 61.48 for the first 6 hours, 39.96 mgms. for the next 12 hours and 48.29 mgms. for the last 6 hours. After 26 hours storage the tipburn plot respired 44.96 mgms. for the first 6 hours, 41.48 mgms. for the next 12 hours and 58.97 mgms. for the next 6 hours. For the commercial plot the rate for the first 6 hours was 32.84 mgms., 29.69 mgms. for the next 12 hours, and 38.71 mgms. for the last 6 hours.

Lettuce from the tipburn plot showed the highest respiration intensity. The initial rate in the material not stored was high, the temperature of storage being lower than the room temperature. The differences in respiration intensity at different intervals after harvest are also shown. The initial rate is high, the second period low, with the third analysis tending to rise. After 26 hours storage the last analyses were higher than the first analyses. This indicates that after an initial high rate the intensity temporarily drops but again rises.

Occluded gases: The composition of the atmosphere between the leaves within the head and of the intercellular gas were determined. Lettuce was obtained directly from a commercial crate before the ice had melted, one lot being taken from the outside layer and one lot from the center of the crate. The lettuce temperature was 2 degrees F. lower in the center than in the outside layer. In withdrawing the gas the salt solution and vacuum method was used, as previously described. Three samples were withdrawn, each succeeding the other without additional air being admitted to the jar. The results are shown as follows:

The first analyses of the occluded gases from the outside layer of lettuce was 3.32 per cent carbon dioxide and 17.5 per cent oxygen. The center heads were 2.46 per cent carbon dioxide and 19.39 per cent oxygen. The second analyses was 27.8 per cent carbon dioxide and 3.9 per cent oxygen for the outside layer and 19.2 per cent carbon dioxide and 6.8 per cent oxygen for the center heads. The third analyses was 38.1 per cent carbon dioxide and 4.7 oxygen for the outside layer and 49.6 per cent carbon dioxide and 3.2 per cent oxygen for the center layer.

As the first analysis only shows a total of both carbon dioxide and oxygen equal to that of the air, it was presumed largely to be the gas from between the leaves. The second and third samples, however, contained high percentages of carbon dioxide. In the third analysis the center lot of lettuce showed the highest per cent of carbon dioxide and lowest of oxygen. This may have a bearing on the work of De Long (2), that the colder the samples are before allowing to reach laboratory temperatures, the more carbon dioxide there will be in solution in the cell sap. It is likely, however, that the carbon dioxide content of heads from the center was higher because of less adequate aeration in comparison with the heads on the outside of the crate.

Solid mature lettuce heads were obtained direct from the field and the gas from between the leaves analyzed. One lot was stored in a

cellar at 15.5 degrees C. a definite period before analyzing the gas. A third immature lot was also tested at the same time. The results are as follows: The immature lot with no storage contained .713 per cent carbon dioxide and 19.19 per cent oxygen between the leaves. The respiration ratio was .442. The mature lot with 40 hours storage contained .55 per cent carbon dioxide and 19.75 per cent oxygen with a respiration ratio of .652. An immature lot with no storage contained .3 per cent carbon dioxide and 20.1 oxygen with a respiration ratio of .428.

The hard, mature heads showed the greatest percentage of carbon dioxide, with the mature storage lot next, and the immature lot last. The field temperatures were lower than laboratory temperatures, which, perhaps, did not allow any of the lots to come to equilibrium except the storage lot. The storage lot had the highest respiration ratio, although all three lots were low in respiration ratio.

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Some Effects of Irrigation Upon Yield and Quality of Potatoes Produced in the Yakima Valley¹

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IN order to obtain large yields of any crop it is recognized that soil fertility is essential. In the arid region of the Yakima Valley of central Washington, soil moisture deficiency is one of the major factors limiting soil fertility. Consequently irrigation is necessary in the production of any horticultural crop.

METHOD OF PROCEDURE

To determine some effects of different irrigation treatments upon yield and quality of potato tubers, experiments were conducted at the Irrigation Branch Station of the State College of Washington from 1925 to 1930 inclusive. The Netted Gem (Russet Burbank) variety was used. The water content of the soil of each plat was brought up to field capacity just previous to planting. There were six irrigation treatments during most of the experiment. Plat 1 was kept moist throughout the growing season by weekly irrigations of 12 hours duration through each furrow. Plat 2 received approximately one-half the amount of water given Plat 1 by weekly irrigations of 12 hours, alternating furrows so that only one-half of the furrows were irrigated at any one time. Plat 3 was irrigated only once during the growing season and then through alternate furrows so that only a portion of the soil mass was saturated. The plants at that time were in a badly wilted condition. Plat 4 was irrigated similarly to Plat 2 until blossom time, and thereafter similarly to Plat 1. Plat 5 received no water until blossom time and thereafter received the treatment of Plat 1. The treatment of Plat 6 was the reverse of Plat 5, i.e., receiving the irrigation treatment of Plat 1 until blossom time followed by an irrigation given at the same time and in a comparable manner to that received by Plat 3.

Observations were made regarding the type of plant growth on each plot. The potatoes were dug at the end of the season and carefully graded according to U. S. standards with regard to shape and size. Mechanical injuries or insect damage were not considered as these are not influenced by the irrigation practice. In 1930 the plats were duplicated. The rows within the plat were harvested and graded separately. Results from rows receiving the same treatment were almost identical so that the data are combined in the tables. Data from previous years were comparable with respect to yield. Hence, the

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²Acknowledgment is made to Harry Jensen, horticulturist at the Irrigation Experiment Station through 1929 for his part in these studies.

cellar at 15.5 degrees C. a definite period before analyzing the gas. A third immature lot was also tested at the same time. The results are as follows: The immature lot with no storage contained .713 per cent carbon dioxide and 19.19 per cent oxygen between the leaves. The respiration ratio was .442. The mature lot with 40 hours storage contained .55 per cent carbon dioxide and 19.75 per cent oxygen with a respiration ratio of .652. An immature lot with no storage contained .3 per cent carbon dioxide and 20.1 oxygen with a respiration ratio of .428.

The hard, mature heads showed the greatest percentage of carbon dioxide, with the mature storage lot next, and the immature lot last. The field temperatures were lower than laboratory temperatures, which, perhaps, did not allow any of the lots to come to equilibrium except the storage lot. The storage lot had the highest respiration ratio, although all three lots were low in respiration ratio.

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Some Effects of Irrigation Upon Yield and Quality of Potatoes Produced in the Yakima Valley¹

By L. L. CLAYPOOL,² and O. M. MORRIS, *Washington State College, Pullman, Wash.*

IN order to obtain large yields of any crop it is recognized that soil fertility is essential. In the arid region of the Yakima Valley of central Washington, soil moisture deficiency is one of the major factors limiting soil fertility. Consequently irrigation is necessary in the production of any horticultural crop.

METHOD OF PROCEDURE

To determine some effects of different irrigation treatments upon yield and quality of potato tubers, experiments were conducted at the Irrigation Branch Station of the State College of Washington from 1925 to 1930 inclusive. The Netted Gem (Russet Burbank) variety was used. The water content of the soil of each plat was brought up to field capacity just previous to planting. There were six irrigation treatments during most of the experiment. Plat 1 was kept moist throughout the growing season by weekly irrigations of 12 hours duration through each furrow. Plat 2 received approximately one-half the amount of water given Plat 1 by weekly irrigations of 12 hours, alternating furrows so that only one-half of the furrows were irrigated at any one time. Plat 3 was irrigated only once during the growing season and then through alternate furrows so that only a portion of the soil mass was saturated. The plants at that time were in a badly wilted condition. Plat 4 was irrigated similarly to Plat 2 until blossom time, and thereafter similarly to Plat 1. Plat 5 received no water until blossom time and thereafter received the treatment of Plat 1. The treatment of Plat 6 was the reverse of Plat 5, i.e., receiving the irrigation treatment of Plat 1 until blossom time followed by an irrigation given at the same time and in a comparable manner to that received by Plat 3.

Observations were made regarding the type of plant growth on each plot. The potatoes were dug at the end of the season and carefully graded according to U. S. standards with regard to shape and size. Mechanical injuries or insect damage were not considered as these are not influenced by the irrigation practice. In 1930 the plats were duplicated. The rows within the plat were harvested and graded separately. Results from rows receiving the same treatment were almost identical so that the data are combined in the tables. Data from previous years were comparable with respect to yield. Hence, the

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1930 data only are used to express results as it is believed that they are representative and more complete.

The water applied to the plats was not measured. Measurements of water for a number of irrigations on potatoes at another part of the Station grounds and on similar soil, have shown that the soil absorbs about 4 acre-inches of water in 12 hours.

RESULTS

Effect on plants. In Plat 1 the plants grew rapidly after the first irrigation and produced a large functional leaf area early in the season. The foliage was light green in color, characteristic of normal, healthy plants. The leaves ceased functioning because of the normal completion of the life cycle approximately 2 weeks before the first killing frost. The plants in Plat 2 were about 10 days later than those in Plat 1 in attaining full size because their first irrigation was late. The leaves, however, functioned about a week longer than did the leaves on Plat 1. The plants in Plat 3 did not attain a large size, and had the dark green color indicative of a drought condition in the soil. They remained dark green and functional until killed by frost or about 2 weeks longer than the plants in Plat 1. The plants in Plat 4 were comparable to those in Plat 2 in attaining full growth, and in remaining functional for about the same period of time. Plants in Plat 5 were nearly 3 weeks later in attaining full size than those in Plat 1. Upon irrigation the foliage changed from a dark green to the normal light green color. The leaves functioned as late as those in Plats 2 and 4. The plants in Plat 6 grew vigorously, similar to those in Plat 1, during the early part of the season, and functioned to capacity for about 6 weeks. Thereafter, they gradually attained a pale yellowish green color, and died about 2 weeks earlier than those in any other plat.

Effect on yield. Studies on apples and pears have shown a direct correlation between leaf area and the yield and size of fruit. It is not unreasonable to suspect that this same relation holds true with other plants where the yield of the storage organ is considered. In our potato fertilizer plots a close correlation has been found between yield and size of tubers and the dry weight of vines. In plots where soil moisture is one of the primary limiting factors in fertility, a correlation between yield and size of tubers and the functional leaf area would be anticipated. Table I shows the comparative yields of the plats and the percentage gradings according to size and shape which fall into the different U. S. grades.

The yield on Plat 1 where the soil moisture was not allowed to become deficient was $2\frac{1}{2}$ tons greater than on any other plot. In previous years the yield of Plat 1 more nearly approached the yields of Plats 2 and 4. All plots receiving water at regular intervals after blossom time produced 10 tons or more of tubers to the acre. Those plots, however, receiving water regularly, even before blossom time, produced more heavily than others, indicating that the leaves func-

tioned at capacity longer than in the other plats. Plat 6 produced a surprisingly high yield considering the life of the vines. This may be explained by the high functional capacity of the vines until several weeks after blossom time. In 1929, under less favorable weather conditions, Plat 6 produced only one-half as great a total yield as either Plats 1, 2, or 4. Plat 3 produced the lowest yield because the leaves were not allowed to function normally at any time.

TABLE I—YIELD OF POTATOES FROM IRRIGATION PLATS

Plat	Tons per Acre				Per cent Grading by Weight			
	U. S. No. 1	U. S. No. 2	Culls	Total	Per cent U. S. No. 1	Per cent U. S. No. 2	Per cent Culls	Number of Tub- ers in Four 100-ft. Rows
1	10.4	2.1	0.7	13.2	78.8	15.9	5.3	2,069
2	8.3	1.3	0.6	10.2	81.4	12.7	5.9	1,512
3	2.1	2.5	3.0	7.6	27.6	32.9	39.5	1,818
4	8.0	1.9	0.9	10.8	74.1	17.6	8.3	1,714
5	5.6	2.7	1.7	10.0	56.0	27.0	17.0	1,831
6	5.8	3.0	0.9	9.7	59.8	30.9	9.3	1,842

More striking and important than total yield are the comparative yields of U. S. No. 1 potatoes. Plats 1, 2, and 4, receiving water at regular intervals throughout the season, produced both a larger tonnage of U. S. No. 1 potatoes and a much greater percentage of the total crop as U. S. No. 1 tubers. Plat 3 produced scarcely more than one-fourth of the crop in the U. S. No. 1 grade, and these were small.

The differences in the number of tubers produced in duplicate rows and duplicate plats were small, so that differences between plats may be significant, although difficult to explain. Plat 1 produced the greatest number of tubers and Plat 2 the least. Other plats were intermediate. Plats 3, 5 and 6, which were kept dry either part or all of the season produced the same number of tubers.

Effect on tubers. Tubers produced on Plats 1, 2 and 4, which received water at regular intervals, were smooth, well shaped, and of a desirable medium size. The per cent of No. 1 potatoes was uniformly high. No. 2 and cull potatoes were made up of small and slightly misshapen tubers. Tubers from Plat 3 were placed into the No. 2 and cull groups largely because of small size. The tubers in Plats 5 and 6 were generally irregular in size and shape, and contained numerous second growth specimens which reduced their grade. Any check in the functioning of the plants, such as water shortage in the soil, also checks tuber development. When more water is applied and the plant again functions normally the tuber is forced into new growth. This second growth, however, does not proceed as did the first, but takes place at the buds and results in rough, knotty, and misshapen specimens. The irrigation treatment in Plats 5 and 6 resulted in a check in tuber growth early in the season followed by this type of second growth.

The Netted Gem potato is normally elongate elliptical. This shape, however, may vary considerably. The limit of the increase in size is approached in the diameter before it is approached in the length. The ratio of the diameter to length in small tubers therefore more nearly approaches unity than in larger tubers. As the size increases the ratio of diameter to length decreases. Table II shows the average weight, diameter, and length and the ratio of diameter to length of the No. 1, No. 2, and cull potatoes.

TABLE II—AVERAGE WEIGHTS AND MEASUREMENTS OF TUBERS IN DIFFERENT GRADES

Grade	Average Weight (Ounces)	Average Diameter (Inches)	Average Length (Inches)	Ratio of Diameter to Length
U. S. No. 1.....	6.19	2.22	3.70	1:1.67
U. S. No. 2.....	3.34	1.79	2.64	1:1.47
Cull.....	2.49	1.55	2.12	1:1.37

Differences were also evident between tubers of various plots within the same grade. Plats 1, 2, and 4 produced tubers of larger average size than Plats 3, 5, and 6. These tubers also had a smaller diameter to length ratio than on Plats 3, 5, and 6.

CONCLUSION

The data indicate that the grade and yield of potato tubers can be controlled to a large degree by the irrigation practice. Applications of water at regular intervals of from 7 to 10 days throughout the growing season which keep the soil mass utilized constantly above a point of moisture deficiency or the wilting point, will result in the production of smooth, high quality tubers. Any irrigation treatment which at some time in the growing season results in a severe check in growth due to inadequate soil moisture will upon resumption of growth bring about the formation of second growth, knotty tubers. Under irrigation it is a decided advantage to produce large vines which can be kept in a vigorous healthy condition throughout the growing season. In this region the size of vines is usually an accurate indication of yield, inasmuch as they are responsible for the production of all food stored in the tubers. Under conditions where potatoes are grown without irrigation these results may not hold true.

Some Responses of Potato Plants to Spacing and Thinning¹

By L. L. CLAYPOOL,² and O. M. MORRIS, *Washington State College, Pullman, Wash.*

THE number of potato plants a soil will support and the tubers produced from them is a measure of soil fertility. Fertility is largely dependent upon the moisture supply and the availability of nutrient elements in the soil. It is likely that the best spacing distances or the most desirable number of plants to the hill for one locality may not be the most satisfactory for other localities under different climatic and soil conditions. It is, however, of value to determine which are the better practices within a locality where soil and climatic conditions are relatively uniform.

PROCEDURE

In the Yakima Valley at the Irrigation Branch Station of the State College of Washington, several years study has been completed to determine the influence of spacing, distance, and number of plants to the hill upon yield and quality of tubers of the Netted Gem variety. Four different treatments were used in both the thinning and spacing plots, with duplicates in most cases. The rows were planted 32 inches apart. The potatoes from all plats were dug after frost had killed the tops. Records were taken on the total yield, and the yield of U. S. No. 1, U. S. No. 2, and cull potatoes from each plat.

In the spacing experiment the hills were planted 6, 12, 18 and 24 inches apart in Plats 1 to 4, respectively. All other treatments were similar. Only one plant was allowed to grow in each hill. The hills in the plats where the number of plants to the hill were varied were spaced 12 inches apart. Plats 1 to 4 were thinned to one, two, three, and four plants per hill respectively.

RESULTS

Spacing of plants. The size of plants is affected by the planting distance. Larger plants were produced on Plats 3 and 4 than on Plats 1 and 2, but not enough larger to offset the greater number of plants in the 6-inch and 12-inch spacings. Table 1 shows the yield and grade of tubers from the plots for the seasons of 1927, 1929 and 1930.

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The greatest total yields and yields of U. S. No. 1 tubers were produced on Plat 1 each year. The total yields gradually decreased as the planting distances were increased but not in proportion to the change in planting distance. The differences in the U. S. No. 1 yield

TABLE I—YIELD AND GRADE OF POTATOES FROM PLOTS WITH HILLS SPACED DIFFERENT DISTANCES APART

Plat	Year	Spacing	Tons per Acre				Percentage Grading		
			U. S. No. 1	U. S. No. 2	Culls	Total	U. S. No. 1	U. S. No. 2	Culls
1	1927	6	7.26	2.03	0.94	10.24	70.9	19.8	9.3
2	1927	12	6.60	2.18	1.38	10.16	65.0	21.5	13.5
3	1927	18	3.92	4.28	1.02	9.29	42.2	46.1	11.7
4	1927	24	3.12	3.77	1.52	8.42	37.1	44.8	18.1
1	1929	6	4.67	3.01	.79	8.47	55.1	35.3	9.6
2	1929	12	3.41	4.20	.47	8.08	42.2	52.0	5.8
3	1929	18	3.25	2.53	.55	6.34	51.3	39.9	8.8
4	1929	24	1.74	4.12	.63	6.49	26.8	63.5	9.7
1	1930	6	10.43	1.47	.47	12.37	84.3	11.9	3.8
2	1930	12	9.63	1.67	.82	12.12	79.5	13.8	6.7
3	1930	18	7.65	1.45	1.96	11.06	69.2	13.1	17.7
4	1930	24	5.43	1.10	2.98	9.51	57.1	11.6	31.3

were even greater than in total yield and greatly favored the closer plantings. Because of their wide spacing and large size the plants in Plats 3 and 4 produced larger tubers than those in Plats 1 and 2. These larger tubers were rough and inclined to have hollow-heart, whereas the tubers from Plats 1 and 2 were of a medium size, smooth, and free from hollow-heart.

In 1927 records were taken on the average number of tubers per hill, and the average weight of individual tubers from each plat. The data are shown in Table II.

TABLE II—THE AVERAGE NUMBER OF TUBERS PER HILL AND THE AVERAGE WEIGHT OF INDIVIDUAL TUBERS FROM SPACING PLATS FOR THE 1927 SEASON

Plat	Number of Tubers per Hill	Average Weight of Individual Tubers (Ounces)	Total Yield per Acre (Tons)
1.....	2.31	4.88	10.24
2.....	3.49	6.42	10.16
3.....	4.17	7.36	9.29
4.....	4.68	8.00	8.42

An appreciable consistent increase in the number of tubers produced per hill was found as the plants were spaced farther apart. This increase, however, in Plats 2, 3, and 4 was only approximately one-half that necessary to offset the effect of the greater number of hills in the close planting of Plat 1. The tubers also increased in size as the planting distances became farther apart, but not sufficiently to offset the greater yield from the increased number of tubers produced in Plat 1. Nevertheless since with wider spacing, both the

average number per hill and the average size of the individual tubers are proportionately increased, the yield is nearly as large when the plants are spaced 24 inches apart as when they are spaced only 6 inches apart. On fertile soil with adequate moisture, as previously stated, the tubers from the wide spacings are objectionable because of the roughness and the tendency to develop hollow-heart. On less fertile soils or without irrigation the spacings of Plats 3 and 4, however, might produce the best yield of U. S. No. 1 tubers, whereas the spacings of Plats 1 and 2 would produce a large number of small unmarketable tubers.

TABLE III—YIELD AND GRADE OF POTATOES FROM PLATS WHERE THE NUMBER OF PLANTS PER HILL WAS VARIED

Plat	Year	No. Plants per Hill	Tons per Acre				Percentage Grading		
			U. S. No. 1	U. S. No. 2	Culls	Total	U. S. No. 1	U. S. No. 2	Culls
1	1929	1	2.85	3.17	.47	6.48	44.0	48.9	7.1
2	1929	2	3.96	3.72	.40	8.08	49.0	46.0	5.0
3	1929	3	4.75	2.22	.47	7.44	63.8	29.8	6.4
4	1929	4	—	—	—	—	—	—	—
1	1930	1	6.61	1.06	.49	8.16	81.0	13.0	6.0
2	1930	2	10.24	1.43	.45	12.12	84.5	11.6	3.8
3	1930	3	10.20	2.12	.69	13.01	78.4	16.3	5.3
4	1930	4	9.71	2.77	1.14	13.62	71.3	20.3	8.4

Thinning of plants. Plats 1 and 2, with one and two plants to the hill, respectively, produce larger plants than those in Plats 3 and 4 with three and four plants to the hill, respectively. This is in accord with the response of the plants in the spacing experiment. Before the season had progressed far it was difficult to tell one plat from another as the amount of foliage was so nearly the same. Table III shows the yield and grade of tubers for the 1929 and 1930 seasons.

The data obtained from Plat 4 in 1929 are not presented because the plants were injured early in the season by water. In 1930, however, the total yield was in the same order as the number of plants per hill. The greatest yield of U. S. No. 1 potatoes was produced each year on the plats having two or three plants to the hill. Tubers in plats having one plant per hill were larger and rougher than tubers in other plats. Tubers in Plat 4 were smooth but small. More tubers were produced per plant as the number of plants to the hill decreased. Even with their greater size and the larger number of tubers produced per plant, however, the plats with the lesser number of plants to the hill were unable to completely offset the greater yield from the larger number of tubers produced to the hill of Plat 4.

Nevertheless, the potato tends to produce nearly the same total yield on plats having from one to four plants to the hill. In a fertile soil, however, with the hills spaced 12 inches apart, two and three plants to the hill give the largest yield of U. S. No. 1 tubers. In a very fertile soil even four plants to the hill might prove desirable.

In contrast with this in a poor soil one plant to the hill would probably give the best yields of U. S. No. 1. tubers.

CONCLUSION

The data indicate that it is possible to regulate the size and quality of potato tubers, within limits, by the spacing of hills, by the number of plants to the hill, or by a combination of both methods. It should be noted that the number of plants to the hill can be partially regulated by the number of eyes and the size of the seed piece.

Effect of Fertilizer Treatment on the Yield, Quality, and Keeping Qualities of Irish Potatoes

By W. D. KIMBROUGH, *Louisiana State University, Baton Rouge, La.*

ABSTRACT

The complete paper will appear as a bulletin from the Alabama Agricultural Experiment Station.

BLISS Triumph Irish potatoes were grown on new ground plots to which various fertilizer treatments were applied. The quality of the potatoes produced was studied by analyzing them for moisture, sugar, and starch content at digging time and at intervals during the storage season. Shrinkage and keeping of potatoes were studied at storage temperatures of 35 degrees, 40 degrees, and 50 degrees F. Except for yields, the fertilizer treatment had little, if any, effect on the factors studied.

A Late Crop of Potatoes for Oklahoma

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MUCH experimental work has been done on the breaking of the rest period of the potato. In many cases the work has been carried on under conditions unlike those prevailing where potatoes are to be grown as a late crop.

Oklahoma comprises a part of the second-early potato-growing district and produces and harvests practically all her potatoes before June 15. In one year only 33 cars were reported as shipped from the state after July. Because of this earliness and because of the difficulty in keeping this early crop, many farm families are without potatoes during a great part of the year, other than what they buy.

There have been shipped into the state per year during the last few years 3000 carloads of potatoes while there were shipped out of the state approximately 2500 carloads. The amount of seed shipped in for the 15,000 acres of commercial planting together with the 200,000 farmers will not equal more than 500 cars.

It was thought that if a late crop could be produced successfully farmers might grow enough to supply themselves during the winter. The storage problem in this case would be eliminated because potatoes are easily kept in common storage from fall until spring. In this state a second crop is grown in the potato sections by simply planting back potatoes that are left in the field and by using those that are not salable due to being injured in harvesting. These amounts are augmented by the larger potatoes that are missed by the pickers.

This practice does not give a crop every year and the crop produced in good years does not give a satisfactory yield. In one year the author found an instance where a grower produced 75 bushels on an acre where he used water in ditch irrigation.

The yield seems to be correlated with the number of vines started from the seed pieces. Since most of the tubers from the first early crop start one eye, the number of vines has been our guide in studies on breaking the rest periods. Dr. F. E. Denny of the Boyce-Thompson Institute assisted in planning the original chemical treatments, but each year these have been modified somewhat. The yields have been considered and as appears in the accompanying table, the yield per acre is influenced by the stand as well as by the number of plants coming from each seed piece.

All rows having cut seed had only half as much seed by weight. Those treated with NH_4CnS were first to come up, with both cut and whole seed.

The potato plant to be able to produce a second crop must come through the ground in parts of the state about August 10. If the tops come up about the middle of July they are likely to be injured

by the extreme hot weather and may not produce any tubers. In a number of tests with seed that came up in July, no tubers formed or those that formed were very, very small though every tuber produced an average of 4.6 plants and the vines averaged 16 inches in height.

TABLE I—YIELDS OF POTATOES AS AFFECTED BY VARIOUS TREATMENTS

Row	Treatment	No. Hills	No. Plants per Hill	No. Hills	Bu. per A.
1	Check.	111	1.4	70	58.3
2	NaCnS (whole).....	59	1	37	16.6
3	NaCnS (cut).....	3	1	1.27	1.2
4	NH ₄ CnS (whole).....	77	1.2	49	27
5	NH ₄ (CnS) (cut).....	59	1	37	21.1
6	Ethylchlorohydrin (cut) ..	40	1	25	16
7	Ethylchlorohydrin (whole)	78	1.3	24	49.3
8	Thiourea (cut).....	12	1	7.6	9.28
9	Thiourea (whole).....	13	1	8	7.6

Ethylene chlorhydrin, both as vapor and as solution was used, in amounts ranging from 4 per cent to 1 per cent and in treatments from 4 hours to 1 hour with the liquid, and 24 hours with the vapor. In the beginning both cut tubers and whole tubers were treated but after the first year all the tubers were treated whole and cut afterwards. The tubers were always allowed to remain in the air as much as 12 hours before they were planted.

Sodium potassium and ammonium sulphocyanate were used in various amounts and for various times. Thiourea also was used. Other treatments were tried as greening the potatoes in indirect sunlight, bruising them by various methods, holding them at low temperatures, and keeping them in a heated building. In every case the potatoes were planted in the morning in order to place the potato in cool, moist soil.

Potatoes that were grown by the station as a second crop were used for seed for a late crop the next year, that is those that were harvested in 1930 were held until in July, 1931, and then planted. Northern-grown seed held in cold storage from the time it was received in Oklahoma in the spring until about ten days before planting was used and some were planted right out of the storage. Then some potatoes were used that were grown in 1931 in southern Texas. This last allowed a considerable rest period between the time of harvest and the time of planting. The results after 3 years' testing have been more or less consistent. Of the chemical treatments, ammonium sulphocyanate gave the best results both in the greenhouse and in the field. None of the other chemical treatments are at all promising. In fact, the untreated lots each year produced more than any of those having chemical treatments. Though the ammonium sulphocyanate breaks the rest period and causes the potatoes to come up more quickly, the reduction it entails in the number of plants reduces the yield.

However, that treatment, the writer believes, has some merit in it. The whole potatoes, either northern-grown seed held until planting time or second crop held until the following August, have given consistently better results. This year's test with the Texas early crop has been promising. In our main crop, northern-grown seed matures ten days to two weeks earlier than our home-grown seed. With the late crop we must plant it at least ten days later than our home-grown seed.

In two tests out of three, bruising the tubers caused growth to start quicker than in the check but even in this case it was an uneven stand. Some tubers seemed to be injured too much and decay set in. Others, perhaps, were not sufficiently bruised, and were slow about coming up. There seems to be no question but that some mechanical injury shortens the rest period but it should occur about the time of harvesting. At that time, less bruising is necessary and there seems to be less decay after planting.

A small concrete mixer was used as a means of bruising the tubers. Pieces of bricks were put in the mixer with the potatoes and the machine was operated by hand for 3-, 5-, and 8-minute periods. The first treatment seemed to be sufficient and both the 5- and 8-minute periods produced too much bruising. The potatoes were then placed on a cement floor in the shade and allowed to callous. All those showing signs of decay were discarded before planting. This treatment gave the best results as was shown by yield and number of plants to the hill.

One grower used for a second crop the potatoes that went through the grader and planted them about twice as thickly as ordinary seed would be planted. In all of our tests we planted one potato or a piece of potato every 16 inches. This grower found that he had secured a better stand than he had ever had before.

In a field study before the tests were made, permission was secured from a grower to go through a field of second-crop potatoes just as an occasional one was coming through the ground. Of a considerable number of these plants that were dug up, a majority were found to have been injured in some manner during the harvesting of the crop or they showed potato scab. About 10 per cent of them did not show any injury, but these could have been injured and not show it.

It is a common opinion that diseased potatoes planted for a second crop give a better stand than those from clean seed or at least they come up quicker. The author has no check on this opinion to substantiate or disprove it. If it be true, it is probably because the virused or diseased plants mature earlier than those free from disease and thus the rest period is ended earlier.

In one test, two barrels of potatoes were shipped to New York and treated with chemicals by Dr. Denny. They responded readily. Potatoes from the same field similarly treated and planted in Oklahoma did not respond. The writer is of the opinion that the difference in the temperature was the cause of the different results. It is found

that the soil must be moist when potatoes are planted during hot weather or they will decay or if the moisture is sufficient to bring them up but not to allow them to grow they will die off before maturing the crop.

It is believed that as a progress report it can be said that no chemical treatment of those tried is sufficiently successful under our conditions to be recommended for general use. The mechanical injury method is hardly adaptable unless it be further revised.

Either good northern-grown seed planted whole or good Oklahoma seed held from the second crop until the following late summer is promising, and the expense of securing this seed is not prohibitive.

The Relation of Solar and Sky Radiation, Temperature, and Humidity to the Sun-scald of Potatoes in 1931¹

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THE term, sun-scald of potatoes, as used in this publication applies to that type of injury in which the living tissue has been killed. This type of injury cannot be detected in the field when the potatoes are picked up within a few hours after digging. When first noticeable it appears as soft whitish gray tissue varying from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch in depth and covering only part of the surface of the potato. The color of the skin over this injured area has a slightly watery appearance with a narrow and darker area around the margin of the injury. After the sun-scald injury has developed the whole potato soon breaks down and becomes soft.

In spite of the present knowledge concerning the sun-scald of potatoes, this injury does occur on quite a large scale each year. Sometimes when growers think there is no danger of sun-scald they discover for themselves, or learn from the dealer that a rather high percentage of the potatoes harvested a few days previous have broken down as a result of sun-scald.

In 1928, according to the Federal State inspection records, 16.1 per cent of the inspected cars of potatoes that failed to grade U. S. No. 1 showed sun-scald defect in lots from the Norfolk, Va., district and 8.42 per cent in lots from the Eastern Shore, Va., district (1). On the basis of the total number of cars shipped, and figuring 200 barrels per car, it is estimated that there were 16,132 barrels of potatoes which showed sun-scald defect in lots from the Norfolk, Va., district, and 57,795 barrels in the Eastern Shore, Va., district that year.

Sun-scald is likely to occur in all the early and intermediate potato sections when the potatoes are left on the ground too long after digging, or in the tubers on top of unprotected barrels and baskets left in the sunshine too long during periods when sun-scald conditions prevail.

Immature potatoes sun-scald more readily than mature tubers. This may be arbitrarily explained by the development of the cork cells which may serve as some insulation against heat in the mature tubers and the greater amount of skinning in immature tubers. Skinned tubers may quickly develop sun-scald on the areas where the skin has been removed or become black because of the failure of the periderm to grow (3).

¹The authors wish to express their appreciation to H. H. Kimble, W. J. Humphreys, and I. F. Hand of the U. S. Weather Bureau, for the solar and sky radiation records and helpful suggestions, and to L. B. Aldridge of the Astrophysical Division of the Smithsonian Institute for his helpful suggestions.

A letter dated July 21, 1931, and received by the U. S. Department of Agriculture expresses the need for and the aim of the sun-scald investigation. The letter reads in part as follows:—"I would like to obtain information relative to the conditions under which sun-scalding of potatoes occurs in the field after digging. Sun-scalding of potatoes has become a serious problem in this county. We would like to work out a telephone relay system whereby we can advise potato growers when to stop digging because of the danger of sun-scald."

When the authors have definitely determined the exact conditions under which sun-scalding of potatoes occurs the object of the investigation will be fulfilled. They have learned that there are several complicated factors that may enter into the sun-scalding of potatoes. If the air temperature could be used as a gauge to indicate when potatoes would sun-scald the problem would be an easy one to solve. But since there are several factors that make up what is termed weather, the problem is not an easy one to solve.

METHOD OF PROCEDURE

The Irish Cobbler variety was planted April 1, 1931, on the Arlington Experimental Farm, Va. The vines were dead when harvesting started on the 29th of July. The period of harvesting extended from this date to September 2, and potatoes were dug every day except week ends and when the ground was too wet. They were dug on scheduled time at 8:30 a. m., 11:30 a. m., and 2:30 p. m. Bushel lots of potatoes were picked up periodically during the day harvested and the following day and taken immediately to the storage located only a short distance from the field. There were 173 bushel lots used in this experiment during 1931 besides many smaller lots.

The potatoes were stored at a controlled temperature of 90 degrees F. and medium humidity. In selecting this temperature and humidity, the authors aimed to duplicate as near as possible the average condition under which potatoes are held when in transit for the first few days after harvest during the summer months. The tubers were examined for sun-scald injury on the third day after harvest.

There are apparently several factors that enter into the sun-scald injury of potatoes. Some of these are solar and sky radiation, which are influenced by humidity of the air, dust particles in the air, and clouds; air temperature; tuber temperature; the velocity of the wind; the amount of moisture in the soil; and the maturity of the tubers. These factors are so interrelated that it is rather difficult to point out the amount of sun-scald injury caused by any one factor.

SOLAR AND SKY RADIATION,² TEMPERATURE, AND HUMIDITY

Perhaps the chief controlling atmospheric factor causing the sun-scald of potatoes is the amount of solar and sky radiation striking

²Some factors affecting solar and sky radiation are explained in the paper entitled,—"The healing of potatoes skinned during harvest as affected by solar

the horizontal surface of the earth. This depends upon the relative position of the sun to the earth and the amount of dust and moisture particles in the air. The ratio of the direct solar radiation to the sky radiation as measured on a horizontally exposed surface is larger for the former but varies with the solar zenith distance (2).

The solar and sky radiation affect the temperature of the air and absorbing bodies like potatoes. But other conditions may change these temperatures. A striking example of this phenomenon was found by Byrd's Antarctic expedition party on the mountains of Little America. When the cold air from the snow and ice was cut off the temperature of an absorbing body in bright sunshine became very high due to radiation from the sun.

TABLE I—COMPARATIVE RESULTS IN THE SUN-SCALDING OF POTATOES WHEN THE AIR TEMPERATURES OF TWO DIFFERENT DAYS ARE PRACTICALLY IDENTICAL

Date and Time Dug	Time Gathered	Air Temperature (Degrees F)				Per cent Injury	Weather
		8:30	11:30	12:30	2:30		
Aug. 14, 8:30 a.m.	11:30 a.m.	76	6	—	—	0	Cloudy
Aug. 14, 11:30 a.m.	2:30 a.m.	—	84	84	80	0	Cloudy
Aug. 31, 8:30 a.m.	11:30 a.m.	76	80	—	—	3.2	Nearly clear
Aug. 31, 11:30 a.m.	2:30 p.m.	—	80	81	82	20.6	Nearly clear

When potatoes are exposed for 2 or 3 hours to high solar and sky radiation a rather high percentage of sun-scauld may result, although, there appear to be a few unexplainable exceptions to this rule at present writing. Solar and sky radiation are intense on clear days during the summer and between 9:00 a. m. and 3 p. m. This may be called the sun-scauld period. The highest record for 1 hour made during the period of the 1931 investigation was 81.0 gr.-cal. per cm² of horizontal surface between 12:00 and 1:00 p. m. on August 24.

As pointed out above if air temperature could be used as an indicator as to when sun-scauld conditions existed the growers could easily tell when not to allow potatoes to remain exposed to the sun. The air temperature near the earth's surface is not only affected by the solar and sky radiation but by the amount of moisture in the soil and in the air and by air movements.

There is considerable variation in the amount of sun-scauld injury that is likely to take place at any one temperature above the danger point. According to this year's results it seems to be rather dangerous to expose potatoes to the sun during the middle of the day at an air temperature of 80 degrees F. or above on practically clear days.

Table I indicates that air temperature alone cannot be used as a guide. The average temperature for the periods taken on August 14 was greater than for similar ones August 31. There was no sun-scauld injury on August 14 but on the 31st the injury resulting from a

and sky radiation, temperature, and humidity," published elsewhere in these Proceedings.

11:30 a. m. to 2:30 p. m. exposure was 20.6 per cent. Also the results of these days emphasizes the influence of solar and sky radiation. The solar and sky radiation was low during the cloudy day of August 14 averaging only 36.0 gr.-cal. per cm² of horizontal surface for the

TABLE II—PERCENTAGE OF SUN-SCALD INJURY TO POTATOES HARVESTED AT 8:30 A. M. AND PICKED UP AT DIFFERENT PERIODS

Date Dug	Time Picked Up			
	9:30 a.m.	11:30 a.m.	3:30 p.m.	8:30 a.m. Next Day
July 29.	—	12.6	47.9	6.5
July 30.	6.2	34.6	28.4	14.5
July 31.	10.8	10.8	19.8	8.5
Aug. 4.	4.8	17.5	16.5	14.4
Aug. 5.	2.6	14.8	18.5	4.6
Aug. 6.	2.8	18.5	35.0	5.7
Aug. 7.	4.9	18.5	26.8	12.1

6-hour period between 9:00 a. m. and 3:00 p. m. (apparent time), while on the clear day of August 31, with an occasional cloud passing over the sun, there was an average of 60.0 gr.-cal. per cm² of horizontal surface for the same period.

The humidity of the atmosphere near the earth's surface usually runs low during the middle of clear days and higher both in the morning and towards evening. It is only reasonable to expect that the low humidity during the mid-day may aid in the development of the

TABLE III—COMPARATIVE RESULTS IN THE SUN-SCALDING OF POTATOES DUG AT DIFFERENT TIMES AND GATHERED AT THE SAME PERIOD

Dug at 2:30 p.m. and gathered at 11:30 a.m. the Next Day				Dug at 8:30 a.m. and gathered at 11:30 p.m. the Same Day			
Date Dug	Tuber Temperature the Day Gathered (Degrees F)		Per cent Injury	Date Dug	Tuber Temperature the Day Gathered (Degrees F)		Per cent Injury
	8:30 a.m.	11:30 a.m.			8:30 a.m.	11:30 a.m.	
Aug. 4	90	108	5.3	Aug. 5	82	107	14.8
Aug. 6..	92	114	7.2	Aug. 7	81	114	18.5
Aug. 17.	82	98	6.1	Aug. 18	78	98	12.9
Aug. 31.	82	106	5.6	Sept. 1	71	101	10.0
Sept. 1..	86	106	5.3	Sept. 2	74	100	4.8
Average	86.4	106.4	6.3		77.2	104.0	12.2

breakdown of the outer cells of the tubers where the greatest exposure takes place. It has been found that a moist atmosphere aids in the healing of skinned tubers (3) and may help in building the cork cells of the skin.

RETARDING THE DEVELOPMENT OF SUN-SCALD

The investigation of 1931 substantiates previous results of this experiment in that less sun-scauld will occur when the tubers are left

out over night rather than picking them up at mid-day after they had been exposed to the sun for a few hours, as shown in Table II. Less injury might have occurred if the tubers had been picked up earlier than 8:30 a. m. This retardation is probably due to the cooling off of the tubers which seems to check the injury and the toughening up of the outer tissues of the potatoes.

Table III shows that the average percentage of sun-scald injury in the potatoes dug at 2:30 p. m. and picked up at 11:30 a. m. the next day was 6.3 per cent and those dug at 8:30 a. m. and gathered at 11:30 a. m. the same day was 12.6 per cent. It also indicates that the tuber temperature of those dug the day before gathering was higher at 8:30 a. m. and 11:30 a. m. the day picked up than those dug and gathered the same day.

Storage temperature has been found to be a controlling factor in the subsequent sun-scald injury of potatoes (4). Storage temperatures of 40 and 60 degrees F. practically stopped the development of the injury in comparison with potatoes from the same lots stored at 90 and 95 degrees F. in 1931.

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The Healing of Potatoes Skinned During Harvest as Affected by Temperature, Humidity and Solar and Sky Radiation

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THE writer has frequently observed during the summer months in the wholesale markets in Washington, D. C., potatoes that have turned dark brown or black where the skin has been accidentally removed in handling. These dark-colored skinned areas are sometimes moist and feel slippery to the touch, and at other times they are dry. Tubers in the latter condition are likely to keep better. Since this type of injury has been found to take place within a few days after harvest, and potatoes from the early and intermediate producing sections are sent to many markets, this injury may be found as frequently in other markets as in Washington, D. C.

This discoloration of the skinned areas appreciably injures the appearance of the potatoes. It is quite evident that a considerable loss in weight takes place through the skinned areas when not properly healed over as shown by the visible shriveling resulting from loss of water. Lutman (4) found that wounding increased the respiration of potatoes. It was found in this investigation that the loss of weight by potatoes with dark areas was much greater than by those in which the injured areas healed quickly.

Under proper healing conditions a skin periderm forms over the skinned areas which has more or less the appearance of the original skin. Pieces of the original rubbed-off skin may remain attached to the tuber and give it a "feathered" appearance. When these skinned areas are properly healed and these "feathered" particles of skin are removed, the skinned areas are scarcely perceptible at a short distance from them. Furthermore, when a skin periderm develops quickly very little shrinkage in weight of the tubers takes place.

MATERIAL AND PROCEDURE

The potatoes used in this experiment were mature Irish Cobblers from the early crop planted the middle of April, on Arlington Experiment Farm, Va. The vines died during the first week in August. The potatoes were harvested for this experiment during the period of September 2 to 11, inclusive. The skin had set so that skinning did not occur as a result of the ordinary harvesting operations.

Small areas on two opposite sides of the tubers were skinned by hand. Care was taken in the skinning operation not to injure the tissue below the epidermis. They were laid out on freshly stirred soil with one skinned area exposed to the sun and the other next to the ground. The time of exposure in the field varied from $\frac{1}{2}$ to $20\frac{1}{2}$ hours.

At the end of the periods of exposure in the field, the potatoes were placed within a few minutes in 32, 40, 50, 60, 70, 80, and 90 degrees F. storage rooms in which the saturation deficit was the same for all the rooms, and with relatively high humidities. Several times while the potatoes were in storage examinations were made for injury in the form of killed tissues.

The solar and sky radiation measured in gram-calories per square centimeter of horizontal surface, the air temperature about 18 inches from the ground, and the humidity at the same height were recorded.

The darkening of the skinned areas under the mid-day climatic conditions of early September on fair days became slightly perceptible within 2 hours after being exposed for a period of 1 or more hours. This type of injury increased until the skinned areas became brown or black, within 24 hours, according to the length and time of exposure, regardless of whether they were left in the field or stored in rooms with the temperature ranging from 32 to 90 degrees F.

One-half hour exposure to the climatic conditions of a clear sky early in September and at midday did not apparently affect the normal healing of the skinned areas, and a light-colored surface was produced. An exposure of 1 hour under similar conditions caused a light-brown color to develop over the skinned areas. An hour and a half exposure produced either dark-brown or black areas. An exposure of 2 hours or longer under midday clear sky produced black areas where the skin had been removed. In these blackened areas skin periderm failed to develop.

Early-morning and late-afternoon exposures did not affect the normal healing. Tubers skinned and exposed at 4 p. m. and left out until noon the next day showed very little evidence of injury; while those treated the same way at 10:30 a. m. and picked up at noon were injured.

SOLAR AND SKY RADIATION, TEMPERATURE, AND HUMIDITY

Radiation may be defined as the transmission of heat or light energy from one body to another, through a vacuum or through an intervening medium without affecting the temperature of this medium. Many solids and liquids allow radiant heat to pass through without being themselves warmed to any great extent; e.g., rock salt and bisulphide of carbon. Other bodies, such as metal, slate, wood, potatoes, etc., do not permit its passage; they absorb the energy and therefore become heated.

The quality and amount of radiation reaching the earth's surface depends upon the freedom of the air from moisture and dust particles. Both moisture and dust in the air check the transmission of solar energy to the earth. They scatter and absorb the short waves of the ultra-violet end of the spectrum more than they do the long wave lengths of the red end, thereby affecting both the amount and quality of solar energy that may come in contact with potatoes at harvesting time.

Since radiant energy as it reaches the earth's surface is made up of both solar and sky radiation and may enter into the injury of the potatoes, it is well to have an understanding of certain factors affecting radiation reaching the earth. The former is the direct radiant energy transmitted from the sun and the latter is the solar radiation which has been reflected by clouds, moisture, and dust particles in the sky. As measured on a horizontally exposed surface, direct solar radiation is usually greater than sky radiation but varies with the solar zenith distance according to Kimball (3). The solar radiation is greater than the sky radiation except for the early-morning and late-afternoon periods and when the sky is overcast.

Radiant heat travels with the same rate of speed as light, according to Duff (2). A good illustration of this fact is found when there is a total eclipse of the sun, when both light and radiant heat are cut off simultaneously. Radiant heat can be reflected and refracted the same as light. Without taking these facts into consideration it is difficult to understand the variability in the amount of injury to potatoes from this cause. For example, when the sun is shining brightly and heavy clouds in the opposite direction are reflecting part of the radiation falling upon them, the temperature goes up, and part of the reflected light from the clouds strikes the earth. Another fact to bear in mind is that the light waves which affect the eye consist simply of those radiations whose length lies between 0.0004 and 0.000076 mm. These waves lie near the end of the entire known range of radiation wave lengths, which is from 0.0001 to 0.3480 mm. and is called the radiation spectrum.

The radiant energy per unit in a stream of radiation is known as the "energy density of radiation," and the solar constant is about 1.3×10^6 ergs per cm^2 per second. Richtmeyer (5) relates that the energy density of the sun's radiation in the neighborhood of the earth is 4.3×10^{-5} ergs per cubic centimeter.

Due to the interrelationship of solar and sky radiation, air temperature, and humidity of the air, it is difficult to figure out the amount of injury caused by any one of these three factors. The author is quite convinced that each plays an important part.

Skinned potatoes that were exposed to the atmospheric conditions during a period when the solar and sky radiation measured in gram-calories per cm^2 of horizontal surface was low, were not injured, even though the air temperature remained high, but were injured during the middle of the day when solar and sky radiation were high.

Air temperature does not change as rapidly as the temperature of the potatoes. The rapid change in the temperature of the tubers is caused by the quick change in the transmission of radiant heat. For example, a medium-size cloud passing over the sun will rapidly change the temperature of the tubers, while the change in the air temperature may be scarcely perceptible. However, there is a correlation between solar and sky radiation as measured in gram calories per cm^2 of horizontal surface and the air temperature. The air warms up as

the radiant heat is absorbed by the earth. Consequently, injury to the skinned exposed surfaces usually takes place when the air temperature is high during the middle of the day.

At the time when the solar and sky radiation is the highest, the humidity of the air near the earth's surface is usually low. Dry air absorbs moisture from the recently skinned areas of the tubers and checks the development of the skin periderm. Any factor which may aid in the checking of the development of the periderm may make the skinned surfaces of the tuber turn dark.

The skinned side of the tuber next the ground developed a normal-appearing periderm regardless of the time of day the tuber was exposed in the field. Since the potatoes were spread out on freshly stirred soil, the humidity surrounding the skinned areas touching the ground was higher than that of the opposite skinned surface due to the checking of the evaporation of moisture from the tubers. Likewise, the temperature of that side of the tuber was lower, and it received no solar and sky radiation.

EFFECT OF STORAGE TEMPERATURE

The potatoes, after being exposed in the field, were stored at 32, 36, 40, 50, 60, 70, 80, and 90 degrees F. Those on which the skinned areas were injured by exposure in the field turned dark in storage regardless of the storage temperature, although storage temperatures of 50 and 60 degrees F. did seem to check to some extent the darkening of the skinned areas of the tubers that were on the injury margin. Those not injured in the field remained light colored at all the temperatures for the short time in storage. It has been demonstrated by Artschwager (1) that a periderm does not develop on cut surfaces of potatoes at 32, 36 and 40 degrees F.

CONCLUSION

To prevent discoloration of skinned areas on potatoes on clear days during the summer harvest, they should be dug preferably early in the forenoon or late in the afternoon. If dug during midday the potatoes should be picked up almost immediately and protected from the sunshine.

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Proximal Dominance in the Sweet Potato

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THE phenomenon of dominance or the advantage in growth one portion of an organism has over another has been extensively studied by physiologists. The existence of regional dominance in the sweet potato (*Ipomoea batatas* Lam.) was indicated to the authors by observations that roots bedded for slip production developed most of their sprouts on the proximal end. This suggested the investigation outlined in this paper.

The structure of the edible portion of the plant (commonly referred to as sweet potatoes) has been studied by a number of workers, especially Schmitz (1), McCormick (2), Hasselbring (3), and Artschwager (4). The work of Artschwager shows quite conclusively that the edible portion of the sweet potato is a thickened root. His careful anatomical studies of the sweet potato root show no structural differences which might account for dominance of one part over another. However, it would be expected that the sweet potato root would exhibit polarity as do other roots and stems. None of the workers mentioned have given attention to the matter of proximal dominance in the root of this plant and as far as we have been able to ascertain, it has escaped the attention of investigators. Appelman (5) clearly demonstrates the dominance of the apical bud of the potato tuber (*Solanum tuberosum*) over the other buds on the same tuber and shows that this dominance can be broken by various means. The purpose of the investigation reported in this paper was to study the extent or degree of dominance in the sweet potato root and to determine if dominance could be broken.

MATERIALS AND METHODS

The work was conducted at the Arlington Experimental Farm, Rosslyn, Virginia. The Porto Rico was selected for this work because it is one of the most generally planted varieties throughout the large sweet potato producing sections of the South. A uniform stock of roots not less than 2 inches in diameter and 4 inches long were selected in the field at Florence, South Carolina, on October 13, 1930. The roots were packed in one-bushel ventilated baskets and shipped at once to the Arlington Experimental Farm, Rosslyn, Virginia. On arrival they were immediately placed in a storage house and cured for 10 days at a temperature of 29 degrees C. after which the temperature was reduced to about 15 degrees C. where it was maintained as nearly as possible during the storage period. Owing to the nature of the heating equipment the temperature in the storage house fluctuated more than was desirable but all material used was subjected to the same storage conditions.

During the period from January 18 to 21, 1931, uniform specimens from the stored stock were selected and prepared for bedding. Six lots of material were treated as follows: (1) Whole roots were bedded as is done in commercial plant growing, (2) roots were cut into two approximately equal pieces and bedded with a space of about 2 inches between the halves, (3) roots were cut into three approximately equal pieces and separated in bedding, (4) roots were cut into four approximately equal pieces and separated in bedding, (5) roots were bedded after removing about 3 centimeters of the tip of the proximal end, and (6) roots were bedded after removing a ring of tissue about 2 centimeters wide and 2 centimeters in depth from the middle of the root.

After preparation, all lots were bedded in clean, washed, river sand placed in raised beds in a greenhouse. All lots were covered to a uniform depth with sand. The beds were watered and otherwise treated alike. The temperature was kept at 21 to 24 degrees C. On March 12, 1931, all specimens were examined and counts made of the sprouts.

RESULTS

The results of the various treatments are shown in the following tables. The eleven roots bedded whole produced 62 slips all of which developed on the proximal end.

TABLE I—PORTO RICO VARIETY SWEET POTATO ROOTS BEDDED IN SAND WITHOUT CUTTING

Number of Specimen	Sprouts on Proximal End	Sprouts on Middle Portion	Sprouts on Apical End
1	4	0	0
2	3	0	0
3	8	0	0
4	7	0	0
5	7	0	0
6	7	0	0
7	9	0	0
8	2	0	0
9	13	0	0
10	1	0	0
11	1	0	0
Total.....	62	0	0

In making the counts recorded on this lot, the roots were arbitrarily considered as consisting of three approximately equal zones, proximal, medial, and distal. Whole roots do not always show such marked dominance as was exhibited by the 11 specimens in this lot. Quite often one or two or even more sprouts will appear on the apical end. Now and then a root was found which lacked dominance altogether as sprouts were produced in about equal numbers throughout the entire length of the root. Further study of this type of root is being made at this time along with some other phases of the problem.

Sprout production on roots cut in two, three, and four pieces show that the cutting of the root resulted in sprout production throughout the entire length of the root and in comparable numbers on the various sections.

TABLE II—PORTO RICO VARIETY SWEET POTATO CUT IN THE MIDDLE AND BEDDED IN SAND WITH THE HALVES SEPARATED ABOUT 2 INCHES

Number of Specimen	Sprouts on Proximal End	Sprouts on Apical End
1	5	8
2	5	3
3	7	4
4	5	6
5	3	4
6	3	7
7	5	1
8	2	1
9	4	3
10	4	4
11	3	3
12	3	3
13	3	8
14	4	3
Total.....	56	58

TABLE III—PORTO RICO VARIETY SWEET POTATO CUT IN THREE PIECES AND BEDDED IN SAND WITH THE PIECES SEPARATED ABOUT 2 INCHES

Number of Specimen	Sprouts on Proximal End	Sprouts on Middle Portion	Sprouts on Apical End
1	5	1	2
2	4	2	3
3	3	3	4
4	2	6	5
5	5	4	6
6	2	2	3
7	2	1	2
8	5	3	6
Total.....	28	22	31

TABLE IV—PORTO RICO VARIETY SWEET POTATO CUT IN FOUR PIECES AND BEDDED WITH PIECES SEPARATED ABOUT 2 INCHES

Number of Specimen	Sprouts on Proximal End	Sprouts on Second Section	Sprouts on Third Section	Sprouts on Apical End
1	3	2	4	2
2	2	2	3	4
3	4	1	2	1
4	2	1	1	3
5	2	0	1	2
6	2	1	1	1
7	*4	3	2	2
8	3	4	5	6
9	4	0	0	1
Total.....	26	14	19	22

It will be noted that in the three- and four-piece lots there was a tendency for the two end pieces to produce slightly more sprouts than the middle sections even though the pieces were approximately of equal size. This can likely be accounted for by the fact that there

TABLE V—PORTO RICO VARIETY SWEET POTATO BEDDED IN SAND AFTER REMOVING ABOUT 3 CENTIMETERS OF THE PROXIMAL TIP OF EACH SPECIMEN

Number of of Specimen	Sprouts on Proximal End	Sprouts on Apical End
1	4	12
2	8	10
3	9	8
4	7	4
5	13	1
6	14	10
7	6	7
8	11	7
9	9	9
10	15	10
11	5	4
12	2	1
13	7	9
14	0	12
15	5	5
Total.....	115	109

was greater skin surface on the end pieces and the production of sprouts is limited to the normal skin surface, *i.e.*, sprouts never develop on the cut surfaces.

TABLE VI—PORTO RICO SWEET POTATO RINGED AT THE MIDDLE TO A DEPTH OF ABOUT 10 MILLIMETERS AND BEDDED IN SAND

Number of Specimen	Sprouts on Proximal End	Sprouts on Apical End
1	3	0
2	6	3
3	4	0
4	6	0
5	4	1
6	7	0
7	7	0
8	4	2
Total.....	41	6

The 15 roots from which a small piece was removed from the proximal end produced 115 sprouts on the proximal end and 109 sprouts on the apical end, showing that the removal of a small amount of tissue from the proximal end of the root was sufficient to break the dominance. The production of sprouts on specimens which had been ringed shows that dominance was not broken.

While a few sprouts were produced on the apical end of some of the roots in this lot there were no more than might be expected if the

roots had not been girdled. As has already been stated some roots do not exhibit complete dominance. Since the sprouts develop from tissue near the surface, it was thought that a severing of this tissue by ringing might interrupt the movement of some principle between the two ends and thereby influence sprout production. The results from this lot would indicate that complete severing of the root is necessary to break the dominance.

As shown in Table VII there is an increase in plant production per gram of seed stock resulting from the cutting of the root before bedding.

TABLE VII—NUMBER OF PORTO RICO SWEET POTATO PLANTS PRODUCED FROM SEED STOCK BEDDED WHOLE, CUT IN TWO PIECES AND CUT IN THREE PIECES

Treatment	Weight of Seed Stock (Grams)	Number of Plants	Grams of Seed Stock per Plant
Whole.....	6493	335	19.4
Cut in two pieces.....	7048	414	17.0
Cut in three pieces.....	7248	557	13.0

The reduction of the number of grams of seed stock required per plant from 19.4 in whole roots to 13 grams per plant in roots cut in three pieces shows a saving of about 33 per cent in seed stock.

DISCUSSION

Various other methods of breaking dominance and other phases of the problem have been and are at present being made, the results of which will be reported in a later paper.

The increase of sprout production per gram of seed stock resulting from the breaking of dominance by cutting may be of commercial importance where seed stock is limited or expensive.

There are some practical difficulties attending the cutting of the roots. The cut surfaces are open to infection by decay organisms and many pieces were lost in some lots from decay originating in the cut surfaces. Treatment of the cut surfaces to prevent decay was not very successful. The cut surfaces suberize quite rapidly at the temperature and humidity generally maintained in plant growing beds. Suberized surfaces are resistant to decay. The practical aspects of the problem need further study to determine whether or not the breaking of dominance may be a profitable practice in the production of draws or slips for planting.

CONCLUSIONS

The proximal end of the enlarged root of the sweet potato (*Ipomoea batatas* Lam.) is strongly dominant in the production of draws or sprouts. This dominance can be broken by sectioning the roots or by removal of the tip of the proximal end. From a practical standpoint the breaking of the dominance of the proximal end of the root may

be of some importance in that it makes it possible to produce a given number of draws with less bedding stock. The loss from decay which may enter the cut surfaces is a factor which must be considered in making practical use of this method of increasing sprout production.

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A Comparison of the Freezing and Alcohol Method in the Preservation of Sweet Potato Samples for Sugar Determinations

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IN connection with a study dealing with the influence of fertilizers upon the storage quality of sweet potatoes, the preservation of specimens for chemical analysis was necessary.

To preserve plant tissue to be used for chemical analysis at a later time, one should use a method of killing that will bring the life processes of the plant to an immediate end at the time of sampling for analysis. No one method will work equally satisfactorily for all tissues under all conditions. A worker should use, as far as possible, the procedure which is best suited for his particular kind of material.

A review of the literature shows three methods of killing: hot alcohol, drying, and freezing. Nightingale, Robbins, and Schermerhorn (6) present results which show that plant tissue of beet leaves, tomato stems, sweet potato stems, and sweet potato storage roots may be preserved by freezing with no modifications of nitrogenous fractions according to the methods employed by them. The temperatures used for freezing trials ranged from -5 degrees to -14 degrees C. With the exception of sweet potato stems, all the plant materials were given two freezing tests, one test of 48 hours and one test of 7 days. In some cases more coagulable nitrogen was extracted from tissue which had been frozen, but the same amount of soluble nitrogen was extracted and the authors (6) concluded that the difference in coagulable nitrogen resulted from variations in the degree of grinding. Haller (2) in studying the changes in pectic constituents of apples killed the tissue by freezing it over night.

Potter and Phillips (7) killed and preserved apple spurs for chemical analysis by the use of hot redistilled 95 per cent alcohol. Appleman and Conrad (1) killed and stored tomato tissue in alcohol. Pectic constituents were studied in that case. Harvey and Murneck (3) used 94 per cent redistilled alcohol to kill and preserve apple spurs for chemical analysis. Kraus and Kraybill (5) killed and preserved tomato plants for chemical analysis by the use of 95 per cent alcohol. Quinn (8) preserved sweet potato roots with 95 per cent alcohol for starch and sugar determinations. Hasselbring and Hawkins (4) killed and preserved samples of sweet potato storage roots in alcohol.

In a preliminary test in which heat at 80 degrees C. was used to kill the samples, difficulty was encountered in drying the large amount of moisture out of the samples. The samples consisted of enough 1-mm. slices to make 100 grams. They were not vigorously aerated in the oven. This preliminary test seemed to indicate that either the freezing or the alcohol method of killing might serve equally well in the

case of sweet potato samples. Therefore, the following experiment was conducted for the purpose of determining the relative merits of these two methods for the killing of sweet potato tissue.

Eight samples of 50 grams each were collected from each of 35 sweet potatoes. The potatoes were cut in two transversely and by the use of a kraut cutter enough 1-mm. slices were taken from each potato to make the 50-gram samples. Four of these samples were dropped into fruit jars containing enough boiling redistilled 95 per cent alcohol to give a final alcoholic concentration of 80 per cent. The alcohol containing the samples was brought back to boiling and the jars were sealed. The other four samples were placed in a cold storage room which had a temperature range from -10 degrees to -20 degrees C. One week later the frozen samples were transferred to the amount of boiling redistilled 95 per cent alcohol required to give a final concentration of 80 per cent. The samples were set aside for one month before the extractions were started.

The alcohol extraction method was used. This method consisted of pouring 80 per cent alcohol onto the tissue and heating just to boiling on a water bath. Then the samples were allowed to cool. After they were cool the liquid was decanted into a liter volumetric flask. The process was repeated until the additional sugar extracted was less than 0.2 per cent of the total extraction.

After completion of the extractions the extract was brought to a liter volume under standard conditions of temperature by the addition of 80 per cent alcohol. Aliquots of 250 ml. of the extract were taken and the alcohol was driven off on a water bath. After making three or four additions of water and subsequent evaporations, about 100 ml. of solution remained in the beaker. When the water solution had cooled to room temperature, an excess (about 2 ml.) of saturated neutral lead acetate solution was added to clear the solution. The lead precipitate was allowed to settle from 2 to 5 minutes and the solution was filtered into a 400 ml. beaker containing sufficient potassium oxalate, about .5 gram, to remove the excess lead. The filter paper was washed thoroughly with distilled water and the solution was filtered again. The residue was thoroughly washed and the filtrate was brought to a volume of 250 ml. Duplicate 50 ml. samples of this solution were used for the determination of the free reducing substances. The Munson Walker Bertrand method was used. The Cu_2O was dissolved with 10 ml. of ferric ammonium sulphate solution and titrated with approximately $\text{N}/10$ KMnO_4 . Titrations were made until duplicate samples checked within 0.2 ml. The copper titration was multiplied by the factor to give the copper in milligrams, and the dextrose equivalent was looked up in Munson and Walker's tables and expressed as reducing sugar.

For the determination of non-reducing sugars, 75 ml. of the above extract were placed in a 100 ml. volumetric flask and 5 ml. of 36 per cent HCl were added. The solution was allowed to sit over night in a warm place. Then it was cooled, neutralized with NaOH , using

alizarine as an indicator, and brought to volume under standard conditions. The reducing power was determined as before, except only 25 ml. of the extract were used for each determination. The titration expressed as dextrose represented the total reducing power after hydrolysis. The increase in the reducing power, due to hydrolysis, represented the non-reducing sugars, commonly called sucrose.

TABLE I—SWEET POTATO STORAGE ROOTS
(Sugar Expressed as Percentage of Green Weight. Samples Preserved as Indicated)

Reducing Sugars		Non-reducing Sugars	
Alcohol Method	Freezing Method	Alcohol Method	Freezing Method
1.06	1.07	5.73	5.65
1.07	1.07	5.86	5.72
1.07	1.06	5.71	5.64
1.07	1.06	5.67	5.67
Ave. 1.07	1.07	5.74	5.67

The results in Table I show that the two methods are equally efficient in killing sweet potato storage roots to be used at a later date for sugar determinations. Therefore, the choice between these two methods for this particular crop is one of convenience.

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A Study of Growth and Development of the Potato Plant

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THIS work is preliminary to a more comprehensive study of the effect of storage conditions of seed potatoes on the growth of the plant and the influence of fertilizers on the setting and development of tubers. There appears to be a scarcity of literature dealing with effects of seed storage conditions and of fertilizers on rate of development of plant and tubers and of movement of organic materials in the plant.

GROWTH OF THE POTATO PLANT

Certified Smooth Rural potatoes, planted May 28, 1931, were harvested at four periods during the growing season. At each harvest period 10 two-stemmed plants were selected, one from each row, and the following data obtained: fresh weight of entire plant, fresh and dry weight of tops, and fresh and dry weights of each individual tuber. All tubers regardless of size were included. Initiation of tuber setting for a majority of the plants occurred about July 2.

Additional tubers were dug at each harvest date and used for respiration studies as previously described.

An increase in fresh and dry weight occurs at each successive harvest with all the plant parts with the exception of the fresh weight of the tops. This decrease at the third harvest period probably is due to the lower leaves drying and some loss of leaves from the plant. Because of the dry condition of the foliage it was impossible at the last harvest to obtain data on the fresh weight of the tops and therefore of the entire plant. When these data are plotted the typical sigmoid curve for rate of growth is obtained. The rather slow rate of growth early in the season shortly after setting, is followed by a rapid rate which tends to drop off late in the season. The small average fresh weights per tuber result from averaging all tubers, regardless of size.

The respiration data are similar to those previously obtained (5) with the White Rose and Irish Cobbler varieties. Respiratory activity is greatest in the earlier-harvested, less mature tubers, and gradually decreases as maturity advances. The decrease in respiration rate is very rapid between the harvests of the very immature tubers but becomes less as the tubers approach maturity.

The tubers were placed in classes according to their fresh weights. These data and the dry weight percentage of the entire tuber population at each harvest are presented in Table II. The dry weight percentages of all tubers on July 25 were practically the same regardless of the size of the tuber. This is not true, however, at any of the subsequent harvest dates. At the second harvest period, on August 11, the dry weights of the different classes of tubers varied from 17.15

TABLE I—GROWTH OF THE POTATO PLANT

Date Harvested	Average per Plant						Average Fresh Weight per Tuber (Gms.)	Mgs. Co ₂ Respired per Kgm. Hr.
	Fresh Weight Entire Plant (Gms.)	Fresh Weight Tops (Gms.)	Dry Weight Tops (Gms.)	Fresh Weight Tubers (Gms.)	Dry Weight Tubers			
					(Gms.)	(Per cent)		
July 25.	428.5 ± 23.68	342.6 ± 17.60	37.56 ± 1.99	52.26 ± 6.22	8.24 ± 1.13	15.79	7.56	38.9
August 11. . .	887.4 ± 37.98	563.4 ± 26.39	72.24 ± 3.08	292.26 ± 14.43	53.73 ± 3.60	18.01	28.41	23.8
September 7. .	1164.0 ± 67.36	460.5 ± 30.78	87.00 ± 5.57	665.86 ± 40.95	142.13 ± 7.50	22.65	57.56	12.4
September 24. .	1	1	102.90 ± 4.51	794.00 ± 25.72	174.86 ± 9.25	22.05	74.12	8.4

Tops dry and dead.

to 19.23 per cent. After that date, however, the differences in dry weight percentages of the tubers of the different weight classes became very great. The dry weight percentages of tubers with fresh weights less than 10 grams rapidly decrease after the second harvest whereas tubers with a fresh weight greater than 10 grams continue

TABLE II—DEVELOPMENT OF DRY MATTER IN TUBERS DURING 1931

Weight Limits (Gms.)	Per cent Dry Weight			
	July 25	August 11	September 7	September 24
Less than 1 gram.....	15.83±0.08	17.15±0.51	11.35±1.10	10.0
1 to 10.....	15.17±0.14	19.23±0.40	17.60±0.67	15.27±1.16
10 to 20.....	15.56±0.26	18.60±0.57	26.40	—
20 to 50.....	15.89±0.45	17.52±0.27	24.22±0.36	22.42±0.79
50 to 100.....	16.57	18.58±0.12	23.03±0.25	23.12±0.26
100 to 200.....	—	17.46±0.14	23.05±0.14	22.54±0.29
Over 200.....	—	—	21.52±0.47	21.65±0.49
Entire tuber population...	15.79	18.01	22.65	22.05

to increase in dry weight percentage until the third harvest. Between the third and fourth harvest the smaller tubers continue to decrease in dry weight percentage whereas the dry weight percentages of the larger tubers change very little, some classes increasing slightly and other classes decreasing in slight amounts. Although there were no tubers in the 10- to 20-gram class at the last harvest, those tubers in the next heaviest class (20-50 grams) have decreased decidedly in dry weight percentage between the third and fourth harvest. These data indicate that all tubers weighing 50 grams or less have decreased in dry weight percentage between the third and fourth harvest or between September 7 and September 24. The average dry weight percentage of the entire tuber population increased up to the third harvest period but decreased slightly at the fourth harvest.

During the fourth harvest it was observed that several of the smaller tubers on each plant had almost completely disappeared, sometimes nothing remained but the entire periderm in the form of a collapsed balloon. In others the disintegration had not progressed so far, leaving the tubers in a wilted, flaccid condition. There was an average of 2.8 resorbed tubers per plant at the fourth harvest when the tops were dead and dry. The number of stolons and the total number of tubers set on each plant were counted at the time of each harvest. The number of tubers less than 0.2 gram in weight and the number of tubers resorbed were recorded again separately. The number of stolons per plant were practically the same at each harvest. The number of tubers set at the last three harvests were practically the same also but at the first harvest the number was considerably less. Clark (2) states that the entire crop of tubers is set within the space of a few days, especially those tubers which eventually reach maturity. These experiments do not completely bear this out. The tubers harvested September 24 were divided into two groups accord-

ing to weight, those above 57 grams, approximately 2 ounces, and those less than that weight. On September 24 each plant averaged 8.2 tubers weighing more than 57 grams each. On July 25, however, the plants averaged only 6.9 tubers set. Evidently some tuber setting occurred after the first harvest on July 25.

TABLE III—FORMATION OF TUBERS DURING THE GROWING SEASON

Date Harvested	Average per Plant			
	Number Stolons	Number Tubers Set	Traces, Less Than 0.2 Gm.	Number Tubers Resorbed
July 25.....	13.9±0.40	6.9±0.21	0.7	0.0
August 11.....	14.0±0.57	10.5±0.98	2.8	0.0
September 7.....	13.3±0.71	10.9±0.34	4.4	0.0
September 24.....	12.4±1.25	10.7±1.02	0.0	2.8

¹Some stolons near the soil surface have decayed and sloughed off.

RATE OF MOVEMENT OF ORGANIC MATERIALS

Dixon (4), calculating from the measurements of only one tuber, concluded that organic substances must travel through the phloem of the stolon into the potato at the rate of nearly 50 cms. per hour. Crafts (3) also using a single tuber, reported the rate of movement of organic materials as 21 cms. per hour through the phloem. Neither of these investigators have calculated the rate of flow of organic materials into the tuber throughout the growing season. It is almost universally held that the phloem is the channel for the downward movement of organic materials from the assimilating organs.

Two-stemmed plants of the Smooth Rural variety planted May 28 were harvested August 11 and September 7. A limited number of tubers were selected and weighed. The stolon of each tuber was cross sectioned, mounted on a slide and the phloem area of each stolon was measured from a micro-projection drawing. By the use of the growth curve of the entire tuber population and the graph showing the relation between the weight of the tuber and the phloem area of the stolon the values of the average weight of each tuber from the time of setting until harvest, and the average phloem cross sectional area of the stolon from the time of setting until harvest were calculated.

The percentage of starch in each tuber was calculated from the dry weights of each tuber by the method of Von Scheele and Svensson (6). These investigators showed that as the dry substance increased the starch increased but not in the same proportion. The differences increase as the dry substance and starch contents increase. From these data the amount of carbohydrate in each tuber at harvest time was calculated. The carbohydrates respired by the tubers from the time of setting until harvest were calculated from the average weight of the tuber during that time, the average temperature of the soil during that same period and the length of time from tuber setting until harvesting. The rate of respiration was obtained from tubers

TABLE IV—RATE OF MOVEMENT OF ORGANIC MATERIALS INTO THE POTATO TUBER

Fresh Weight Tuber when Dug (Gms.)	Average Weight of Tuber from Time of Set- ting Until Dug (Gms.)	Phloem Area of Stolon When Dug (Sq. Mm.)	Average Phloem Area from Time of Setting Until Dug (Sq. Mm.)	Starch Content of Tuber Calcu- lated (Per cent)	Carbohydrate Respired from Time of Set Until Dug (Gms.)	Amount Starch in Tuber when Dug (Gms.)	Amount Carbohydrate went Through Stolon (Gms.)	Amount 15 Per cent Solution went Through Stolon (Cc.)	Linear Rate of Flow Through Phloem (Cm. per Hour)
Trace.....	—	0.19	—	—	—	—	—	—	—
Trace.....	—	0.23	—	—	—	—	—	—	—
0.76.....	0.217	0.54	—	11.90	0.005	0.09	0.095	0.63	3.96
30.52.....	8.74	1.21	0.74	13.15	0.210	4.01	4.22	28.1	3.86
30.82.....	8.83	0.94	0.72	12.80	0.212	3.79	4.00	26.6	6.13
53.34.....	15.28	1.49	0.82	12.90	0.367	6.88	7.25	48.3	6.54
54.45.....	15.60	1.48	0.82	13.44	0.375	7.32	7.70	51.3	9.54
92.26.....	25.44	1.55	0.94	13.29	0.612	12.26	12.87	85.8	8.77
95.84.....	27.46	1.53	0.94	11.71	0.660	11.22	11.88	79.2	9.30
145.49.....	41.67	1.85	1.06	9.08	1.002	13.21	14.21	94.7	13.23
159.25.....	45.63	1.79	1.05	11.87	1.098	18.90	20.00	133.3	10.99
200.65 ¹	77.70	1.94	1.32	16.00	2.930	32.10	35.03	233.5	11.10
213.59 ¹	82.71	1.99	1.34	15.35	3.119	32.78	35.90	239.3	

¹Harvested September 7. All others harvested August 11, 1931.

harvested at the same stage of development and the respiration run immediately after harvesting at the same temperature as the average temperature of the soil during the growing season. The closed system of respiration was used, therefore, the percentage of carbon dioxide in the closed jars surrounding the tubers was similar to that surrounding the tubers in the soil.

A 15 per cent solution of carbohydrate during translocation is assumed. Bushnell (1) has found that the sap in the stem of the potato at times might be more than 15 per cent carbohydrates.

It is necessary to assume that all tubers were set at approximately the same time. The two largest tubers were harvested on September 7, the remaining tubers on August 11.

Table IV presents the data from which the calculations were made, the last column showing the average rate of flow in centimeters per hour for every hour since tuber setting.

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Effects of Light and Temperature on the Growth and Tuberization of Potato Seedlings¹

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EXPERIENCE had shown that it was possible to grow potato tubers to the size of a walnut on seedling potato plants in 3½-inch pots in the greenhouse; that these tubers when properly "after ripened" germinated and grew in the field as satisfactorily as transplanted plants. Under conditions existing at the North Carolina Agricultural Experiment Station it was thought that this method of transporting seedlings to the field would be a great advantage. Of several problems associated with growing seedlings in this manner one was to determine the light and temperature conditions most favorable for tuberization and early maturity in order that greenhouse time and expenses might be reduced.

Two temperatures were available, namely, a cool greenhouse operated at a night temperature of 50 degrees F. and a day temperature of 60 degrees F.; a warm greenhouse operated at a night temperature of 60 degrees F. and a day temperature of 70 to 75 degrees F. By careful regulation these temperatures were maintained within very close limits, the warm house tending to fluctuate more than the cooler one.

Variations in light exposure were secured by lengthening the normal 9.5-hour winter day by suspending 115-volt, 200-watt clear glass Mazda lamps over the treated plants. The lamps were equipped with enameled reflectors and delivered 160 to 260 foot candles at the outer edge and at the center respectively of the area covered by the experimental plants. Four exposures were used as follows; normal day and illumination totaling 12 hours, 15 hours, and 18 hours. The air temperature beneath the lights was maintained at average greenhouse temperature by means of a small fan.

The seedlings used were from selfed seed of the Katahdin variety, transplanted to 3½-inch pots and allowed to mature under the various treatments. The material was quite variable because of its heterozygous nature, though striking abnormalities did not appear. Random samples of the treated plants were secured by taking every fifth plant according to a definite plan such that variations in light, temperature, and vigor would tend to be compensated. Samples were composed of 15 to 18 plants each, except the last set which consisted of 30 to 35 plants each. They were taken at three periods, (1) when the majority of the plants were beginning to form tubers, (2) when the first

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plants were just beginning to mature 14 days later, and (3) when practically all plants had matured 22 days after (2).

The effects of light and temperature upon the length of stem are significant and are presented in Table I. It is seen that temperature has had a marked effect upon the elongation of the stem beginning early and increasing throughout the duration of the experiment. The progressive differences due to the high temperature at the three

TABLE I.—EFFECT OF DAY LENGTH AND TEMPERATURE UPON LENGTH OF STEM OF PLANTS AT THREE SUCCESSIVE PERIODS OF GROWTH. (CENTIMETERS)

Light Conditions	Average Length of Stem—January 5		Average Length of Stem—January 19		Average Length of Stem—February 10	
	50° F. House	60° F. House	50° F. House	60° F. House	50° F. House	60° F. House
Regular day.....	12.84	25.76	17.92	25.64	14.88	23.31
12-hour day.....	15.81	29.32	15.96	38.33	15.49	32.32
15-hour day.....	14.25	34.37	15.74	41.38	16.94	45.72
18-hour day.....	13.47	27.97	16.28	38.03	16.94	47.59
Total.....	56.37	117.42	65.90	143.38	64.25	148.94
Average.....	14.09	29.35	16.47	35.84	16.06	37.23
Difference.....	—	15.26	—	19.37	—	21.17

periods of sampling were 15, 19, and 21 cm. and show the more rapid rate of elongation of the stem at the high temperature. These results are not in agreement with those of Bushnell (2) who found no significant differences in rate of elongation due to temperature though it is likely that the temperatures he used were somewhat above the optimum, the lowest being 68 degrees F. and the highest 84.2 degrees F. in contrast to those employed in this investigation.

At the low temperature the effects produced by the different light exposures appear as random variations in that all plants have approximately the same stem length. At the high temperature on the other hand the 15-hour exposure seems definitely to stimulate early and continued vegetative growth until the final period when the 18-hour plants overtake them. It is clear, however, that temperature has produced the more striking differences and that light exposure has had little or no effect except at the higher temperature.

In contrast to length of stem are the effects on number of leaves, average size and total leaf area of the plants. (See Plate I.) These data are not presented in tabular form in that the variations are small and probably are of little significance. The average number of leaves per plant at the second period was 7.4 at each temperature. The range of the high temperature plants under the different light exposures was 6.7 to 8.7, and for the low temperature plants was 6.9 to 8.4. The total leaf area per plant at the high temperature was 19 square inches compared to 17 square inches for the low temperature plants. Under high temperature the 15- and 18-hour plants, with 21 and 22 square inches respectively had the greater leaf area; under low temperature the 12-hour plants, with 19 square inches had the greatest leaf area.

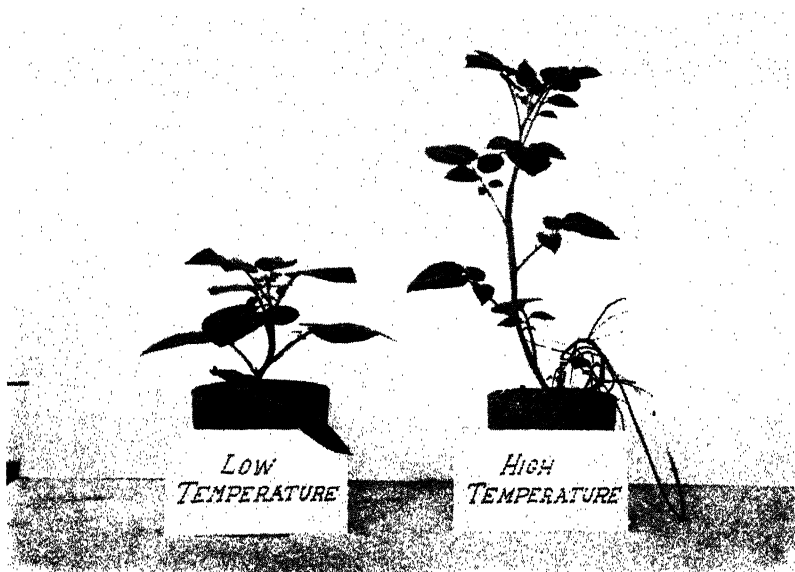


PLATE 1. Showing habit of growth and character of leaves of typical plants from the 15-hour light exposure, low and high temperature plants.

The average size of leaf was remarkably uniform for all groups. The regular day plants at both temperatures had the smallest leaves (1.9 square inch) while the average leaf areas of the 12-hour, low temperature and 15-hour, high temperature plants were 2.7 and 2.9 square inches respectively. It is apparent that all of these differences are small and of doubtful significance, though none the less remarkable in the light of the striking differences produced in length of stem.

TABLE II—PER CENT OF PLANTS MATURE AT FINAL SAMPLING (FEBRUARY 10)

Light Conditions	No. Plants per Sample	Percentage Tops Mature	
		50° F. House	60° F. House
Regular day.....	25	0	100
12-hour day.....	30	23	100
15-hour day.....	29	69	48
18-hour day.....	26	81	7

There was, however, a pronounced difference in shape and indentation of the leaves at the two temperatures. The high temperature leaves were divided into from 3 to 5 leaflets and were heavily pubescent, while those of the low temperature plants were mostly entire and with very little pubescence.

Both light and temperature have profound effects on the maturity of the plants as shown in Table II. At the high temperature the plants under regular day 12-hour exposures had all matured while at the next longer exposures respectively, 48 per cent and 7 per cent only were mature. These results are entirely in line with those secured by other investigators notably Garner and Allard (4, 5), Zimmerman and Hitchcock (6), Arthur, Guthrie, and Newell (1), and Maximof and Rosumov² with the potato at summer temperatures, which indicate that the longer light exposures favored prolonged vegetative growth. In contrast to these, at the lower temperature used in this experiment diametrically opposed results were found which have not been previously reported. It seems, therefore, that the relative difference of 10 degrees F. in temperature has completely reversed the effects of light exposure on maturity.

The salient features of the experiment so far as the economy of the plant as measured by growth and storage is concerned are presented in the following paragraphs. The data for top weight, tuber weight, and total weight at the last period of sampling are combined in Table III. On account of differences in maturity, the falling and loss of leaves and drying of the stem, the top weight could not be secured at the time the tubers were harvested. Consequently the greatest top weight recorded is used as the final weight.

The effects of light and temperature on green weight of the top are presented in the first section of Table III. These data are in line with those secured for length of stem except that the effect of light

²Copy undated received through Office of Horticultural Crops and Diseases, Washington, D. C.

upon green weight at the low temperature is more pronounced and increases to the 18-hour exposure, while at the high temperature the 15- and 18-hour exposures produce approximately equal effects. As was the case with length of stem the higher temperature is slightly more favorable for growth in weight of tops, the average difference being 2.4 gms. per plant. The differences are not uniform at the different light exposures, the greatest difference occurring at the 15-

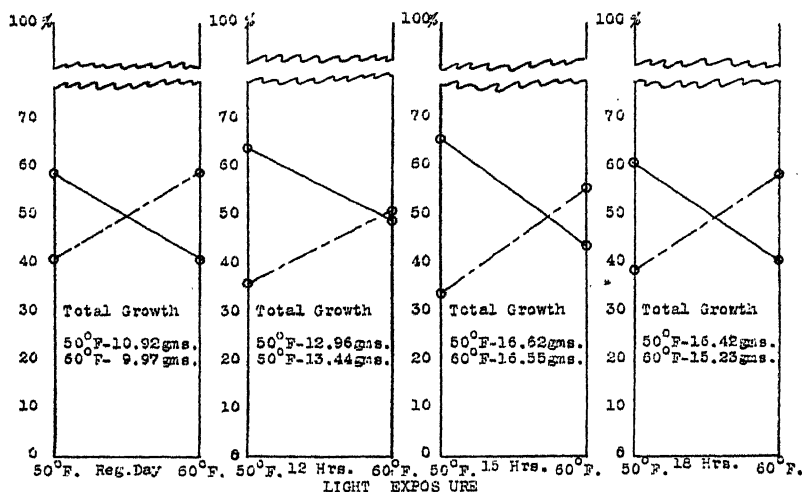


FIG. 1. Percentage of top weight and tuber weight of the total weight under the different light and temperature treatments. Solid line = Percentage tuber weight based on total weight. Broken line = Percentage top weight based on total weight.

hour and the least at the regular day, light exposure. Growth at the low temperature reaches a maximum at 18 hours and the range is not so great as at the high temperature where the maximum is reached at or near 15 hours.

The weight of tubers produced presents striking contrasts to the growth of tops. The difference in tuber weight was -2.8 gms. per plant in contrast to $+2.4$ gms. in weight of top in favor of the higher temperature. The clear maxima noted at the 15-hour high temperature exposure for weight of top and length of stem becomes less prominent when tuberization is considered, while at the low temperature the maximum for top growth shifts from the 18-hour exposure to the 15-hour exposure.

The combined green weight of tops and tubers is shown in the third section of the table. It is apparent that while heretofore the effects of temperature were the more striking and the character of the growth was distinctly affected, by this treatment of the data all effects of temperature disappear and total growth becomes a function of light with the 15- and 18-hour exposures outstanding. The average difference per plant is .4 gm. in favor of the low temperature.

Since total growth seems to be constant at a given light exposure it will be of value to consider more carefully the characteristics of this growth. These facts are brought out clearly in Fig. 1, in which the percentages tuber weight at the two temperatures for each light exposure are joined by solid lines, while the corresponding percentages of tops are joined by the broken lines. Note the complete reversal in behavior of the plants at the two temperatures. Clearly at the 12-

TABLE III—WEIGHT OF TOPS AND TUBERS OF POTATO PLANTS

	Ave. Wt. Tops 2nd Period		Ave. Wt. Tubers (Gms.)—3rd Period		Total Wt. Tops and Tubers—Tops 2nd Period—Tubers 3rd Period	
	50° House	60° House	50° House	60° House	50° House	60° House
Regular day.....	4.46	5.91*	6.46	4.06	10.92	9.97
12-hour day.....	4.68	6.62	8.28	6.82	12.96	13.44
15-hour day.....	5.58	9.22	11.04	7.33	16.62	16.55
18-hour day.....	6.44	9.01	9.96	6.22	16.40	15.23
Total.....	21.16	30.76	35.74	24.43	56.90	55.19
Average.....	5.29	7.69	8.93	6.11	14.22	13.80
Difference.....	—	2.40	—	—2.82	—	—0.43

hour high temperature exposure the plants have reached the point of greatest economy so far as proportion of tubers and tops is concerned with 51 per cent tops and 49 per cent tubers. Longer or shorter exposures than 12 hours decrease the proportion of tubers to tops. At the low temperature on the other hand the greatest economy as indicated by proportion of tubers and tops is reached at 15 hours with 66 per cent tubers and 34 per cent tops. Above and below this exposure the percentage tuber weight decreases. The ratio falls off more rapidly after 15 hours than did the ratio of the high temperature plants.

DISCUSSION OF RESULTS

On the basis of results obtained by Stuart, Bushnell (2, 3), Arthur, Guthrie and Newell (1) and others it seems that we may attempt to account for the low yields at the higher temperature as being due; first, to the balance between growth and storage being shifted toward elongation of the top and second, that this shift does not necessarily result in a greater number of leaves or increased leaf area. The rate of photosynthesis would be increased as well as the rate of respiration. Respiration presumably would be affected more than photosynthesis and consequently a somewhat greater proportion of the photosynthate would be used than at the lower temperature. The cumulative effect of these factors would result in little storage.

The effects of light exposure are more difficult to interpret. Light like temperature affects the balance of growth between elongation and storage as it does between growth and reproduction. Garner and Allard and others have ably demonstrated the latter. The optimum

light exposure may be different for each of these processes at a given temperature and for a single process the optimum may be different at different temperatures as indicated here. Thus the data presented indicate that at the two temperatures respiration presumably remaining constant regardless of light exposure total growth is associated with increased light exposures up to 18 hours, while the point of maximum tuber storage in proportion to total growth occurs at 12 hours at the high temperature and at 15 hours under the low temperature.

From the standpoint of yield and early maturity, the major purpose of this investigation, the 15-hour light exposure in the cool greenhouse has proven most satisfactory. As to why this should be so is a question that will require further investigation.

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Size of Seed Piece and Sprout Removal in Relation to Sprout Formation on Jerusalem Artichoke Tubers

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SIZE of seed piece and the removal of successive crops of sprouts of the potato tuber are known to have a pronounced effect upon the number, size, and vigor of sprouts; upon the number and vigor of stalks per hill; and finally upon the yield and market quality of the crop. The Jerusalem artichoke, like the potato, produces tubers; is propagated by tuber pieces in a manner more or less similar to that used in propagating the potato; and there the chief points of similarity of the two crops end. However, observations of the artichoke have suggested that there might be similarities of behavior incidental to propagation. Inasmuch as the results of Jerusalem artichoke propagation studies in this country are exceedingly fragmentary and inconclusive, a careful consideration of sprout production by tuber pieces is of both academic interest and practical importance.

METHODS

From a bulk lot of tubers of the White Improved variety which had been freshly dug in the spring, numbers of specimens were selected which weighed approximately 10, 20, 30, 40 and 60 gms. each. Twenty-five tubers of each size were cut in halves so that 50 pieces of cut tubers 5, 10, 15, 20 and 30 gms. in weight were available for planting. An equal number of whole tubers of corresponding size was planted beside each lot of cut tubers. One lot of 70 gm. whole tubers also was planted. April 1, 1931, the pieces were placed on moist sand in a greenhouse bench and covered with 4 inches of moist peat moss. After a few sprouts emerged through the peat, all tubers were carefully taken up and the sprouts and roots removed; the number of sprouts per tuber and the total weight of sprouts from each lot of tubers or pieces were recorded. The tubers and pieces were then replanted as before. Data upon five successive crops of sprouts were collected in this manner. In two instances, irregular sprouting, together with some unavoidable delay in taking the data, resulted in the formation of several leaves on a few sprouts. The leaves were removed before weighing.

RESULTS

On account of wide variations in temperature of the greenhouse, the rate of growth of the sprouts must have varied widely from day to day and from one crop to another. Consequently, the time intervals between harvest cannot be taken as indices of relative vigor of growth of sprouts in different crops. Furthermore, an unavoid-

able delay in harvesting the fourth crop of sprouts resulted in total weights that are not comparable with the others. However, accurate comparisons may be made among sprout weights for different seed piece lots on any one harvest date, and for the total sprout production of five crops. It is believed that variations in temperature and time of harvest are without significant effect upon number of sprouts formed, therefore, any and all lots may be compared with reference to sprout number.

TABLE I—COMPARISON OF SPROUT PRODUCTION BY WHOLE TUBERS AND BY THE TWO HALVES OF TUBERS OF COMPARABLE SIZE

Approximate Weight of Total Tuber (Gms.)	Number of Sprouts per Tuber		Weight of Sprouts per Tuber	
	Halved Tubers x 2	Whole Tubers	Halved Tubers x 2 (Gms.)	Whole Tubers (Gms.)
10	13.68	10.80	4.12	3.68
20	20.34	18.46	10.10	6.72
30	36.92	24.65	13.31	10.78
70	47.56	55.22	18.78	16.02

Most of the 5 gm. pieces and over half of the 10 gm. and 15 gm. pieces had decayed between the fourth and fifth crop of sprouts. Practically no losses from decay occurred until after three crops of sprouts had been removed, and these first losses were almost entirely in the 5 gm. pieces. There was no appreciable loss from decay of tubers or pieces over 15 gms. in weight at any time. There were greater losses from decay among the whole tubers than among cut pieces of the same size.

Upon harvesting the fifth crop of sprouts, the tubers appeared to be so nearly exhausted that the study was terminated. The whole tubers appeared normal from the exterior; there was no appreciable shrinkage nor decay, but they yielded easily to pressure. Cutting a large number showed every one to be pithy and to contain large hollow spaces surrounded by semi-dry pithy tissue, especially in the branches of the tuber. Cut surfaces of the cut pieces were well callused over, but greatly distorted by the virtual collapse of the tuber piece, presumably resulting from the exhaustion of storage materials.

In order to determine the effect of cutting upon the total sprout number and weight of a single tuber, the results obtained with cut pieces (halves) weighing 5, 10, 15, and 30 gms. were each multiplied by 2 and compared with the results from whole 10-, 20-, 30-, and 70-gm. tubers. These data are presented in Table I.

Except with the very large tubers, cutting the tuber in halves resulted in a definitely greater number of sprouts produced; and in all sizes, a definitely greater weight of sprouts.

Data upon both whole and cut pieces of different sizes, for the five successive crops of sprouts were compared by Student's Method. Considering the means of only the undecayed pieces, the cut pieces produced 3.17 sprouts per crop each, while the whole

TABLE II.—SUMMARY OF DATA UPON PRODUCTION OF FIVE SUCCESSIVE "CROPS" OF SPROUTS BY JERUSALEM ARTICHOKE TUBERS OF DIFFERENT SIZES

Mean Weight of Seed Piece (Gms.)		Mean Number Sprouts per Piece		Mean Weight Sprouts per Piece (Gms.)		Sprout Size (Mean Wt. Gms.)		Mean Number Sprouts per Gm. of Piece		Mean Weight Sprouts per Gm. of piece (Gms.)	
Cut	Whole	Cut	Whole	Cut	Whole	Cut	Whole	Cut	Whole	Cut	Whole
4.8	5.5	6.84	9.09	2.07	2.89	.302	.318	1.44	1.65	.435	.526
10.5	10.2	10.17	10.80	5.05	3.69	.497	.341	.97	1.06	.480	.361
15.7	14.7	18.46	12.46	6.66	5.30	.360	.425	1.18	.85	.425	.361
20.4	22.2	20.55	18.46	5.81	6.72	.282	.364	1.00	.83	.284	.302
32.7	32.1	23.78	24.65	9.39	10.92	.395	.443	.73	.77	.287	.340
—	69.4	—	55.22	—	16.02	—	.290	—	.79	—	.231

tubers of corresponding size produced 3.02 sprouts. The difference of .15 sprouts per piece was quite insignificant as the odds were less than 2 to 1. Of the three largest sizes, the cut pieces produced 4.18 sprouts and the whole tubers 3.70 sprouts per tuber per crop. The odds of significance were 34 to 1. There was no significant difference in weight of sprouts produced per piece by whole and cut seed pieces of the same size. However, the individual sprouts on the whole tubers averaged very slightly larger than on the cut pieces.

Table II presents the summarized data upon all five crops of sprouts produced. The total number of sprouts produced per piece increased from approximately 8 for 5-gm. pieces to 55 for 70-gm. pieces. Columns seven and eight show no consistent relationship between sprout size and tuber size. However, these total figures upon sprout size do not show the relationship between sprout size and tuber size that was evident in certain crops of sprouts, for which the detailed data are presented later.

Per unit weight of seed piece, the 5-gm. size produced approximately twice the number and twice the weight of sprouts as did the 70-gm. size. The number and weight of sprouts produced per unit weight of piece by the other sizes fluctuated considerably, but in general varied inversely with the size of seed piece. Further consideration of the data will be based upon the combined results of whole and cut tubers.

The third column of Table III shows that in each crop of sprouts, the number of sprouts per piece increased consistently with size of tuber. The fifth column shows, however, that the smaller tubers produced a greater number of sprouts in proportion to tuber weight than did the larger ones. The larger the tuber piece, the greater was the total weight of sprouts produced per piece; but as in sprout number, the small tubers and pieces produced a greater weight of sprouts per unit weight of tuber than did the large pieces (last column). In the first four crops of sprouts there was no significant relation between tuber size and sprout size (fourth column) but in the fifth crop a very high positive correlation existed.

Table III shows that all sizes of tubers responded similarly to sprout removal. The largest number of sprouts per tuber was produced by the second crop, the number being almost double that of the first. The third and fourth crops of sprouts were intermediate in number, while the fifth decreased very markedly, indicating that exhaustion of the tubers was being approached. Considering the total mean number of sprouts per piece, including all sizes, as an index of sprout production we find the following: Initial crop, 21.14; second, 40.75; third 30.98; fourth 30.12; fifth 10.20.

For reasons stated above, no accurate indication can be obtained from these data relative to the effect of sprout removal upon subsequent sprout size except in the case of the fifth crop of sprouts. After removal of four successive crops, the seed pieces were so depleted of the materials requisite for growth that the fifth crop

of sprouts was very small in both numbers and weight. Many small tubers, although free from decay and apparently sound otherwise, produced no sprouts.

TABLE III—GROWTH OF FIVE SUCCESSIVE "CROPS" OF SPROUTS UPON DIFFERENT SIZES OF TUBERS OF JERUSALEM ARTICHOKE

Date of Sprout Removal	Original Mean Wt. of Seed Piece (Gms.)	Mean No. Sprouts per Piece	Mean Wt. per Sprout (Gms.)	Mean No. Sprouts per Gm. of Piece	Mean Wt. Sprouts per Gm. of Piece (Gms.)
Apr. 11	5.1	1.62± .053	.232	.318	.074
	10.4	2.08± .070	.248	.200	.050
	15.2	3.01± .092	.240	.199	.048
	21.3	3.93± .115	.256	.185	.046
	32.4	4.25± .124	.284	.131	.038
	69.4	6.25± .602	.332	.090	.030
Apr. 21	5.1	2.56± .082	.306	.502	.153
	10.4	3.49± .114	.327	.336	.110
	15.3	5.52± .219	.261	.363	.094
	21.7	6.58± .203	.188	.309	.057
	32.4	5.87± .317	.376	.181	.068
	69.4	16.73± .733	.202	.241	.049
May 8	5.1	1.74± .062	.282	.341	.096
	10.4	2.59± .083	.332	.249	.094
	15.3	3.61± .140	.361	.237	.085
	21.7	4.18± .128	.509	.196	.098
	32.4	5.69± .160	.463	.176	.081
	69.4	13.16± .775	.415	.190	.078
May 26	5.1	1.30± .066	.622	.255	.159
	10.4	1.63± .073	.845	.157	.155
	15.3	2.43± .104	.965	.160	.153
	21.7	3.42± .150	.454	.160	.071
	32.4	6.14± .240	.578	.190	.109
	69.4	15.20± 1.016	.273	.219	.059
June 12	5.1	.84± .094	.080	.165	.016
	10.4	.73± .089	.155	.070	.011
	15.3	1.02± .105	.209	.067	.014
	21.7	1.44± .105	.220	.068	.015
	32.4	2.29± .148	.243	.071	.012
	69.4	3.88± .401	.245	.056	.013
Avg. per "crop" of sprouts	5.1	1.588± .031	—	—	—
	10.4	2.096± .043	—	—	—
	15.3	3.102± .073	—	—	—
	21.7	3.906± .080	—	—	—
	32.4	4.844± .102	—	—	—
	69.4	11.050± .330	—	—	—

DISCUSSION

In general, within each crop of sprouts, there was a definitely decreasing number of sprouts per unit weight of seed piece. Even if every bud sprouted we would hardly expect the number of sprouts to increase in proportion to the weight of the seed piece, because neither the surface of the tuber nor the number of buds on the

surface increases proportionally with the volume and weight. Inasmuch as the number of sprouts per unit weight decreases with increase in size of seed piece, it would appear that there is a greater supply of stored materials available for the growth of each sprout, and that the individual sprouts should increase in size with the increase in weight of seed piece supporting each sprout; but this does not occur. If the weight of storage materials alone, in the seed piece, controlled the amount of sprout growth, the total weight of sprouts per unit weight of seed piece should be practically constant; but neither does this occur. Evidently some factor other than weight of stored food supply limits sprout growth in the first four crops of sprouts.

Appleman has suggested that even though there be an abundance of known food materials in a small tuber piece of potato (5 to 10 gms. for example) such a small piece will not produce a good vigorous sprout because of an insufficient supply of some unknown, essential, growth-promoting substance; and that a piece of perhaps 20 to 30 gms. is necessary to supply enough of this substance to support good sprout growth. From this point of view, what is the explanation of the results obtained with artichoke tubers? There is evidently no such shortage of a supposed requisite growth-promoting or growth-controlling substance as in the potato, because in general the small pieces produced as large sprouts as the large pieces in the first four crops of sprouts. In the fifth crop, however, the growth-controlling factor was apparently so nearly exhausted that only the largest tubers contained enough to produce sprouts comparable with those previously produced. The relatively large sprout sizes from large tubers in the fifth crop is due to no greater size of those sprouts but to a very striking decrease in size of sprouts from the small tubers. Even though the size of sprouts remained fairly high in the fifth crop on large tubers, the number had decreased greatly and the size decreased noticeably.

If large tubers possess such an ample supply of stored foods and growth-promoting substances as to still support good sprout development after four sprout removals, while the small tubers have become much depleted, why did the large tubers produce no larger sprouts in the first four crops? The limiting factor may be rate of translocation or of conversion of the requisite materials; or even possibly the rate of utilization by the growing sprout. A greater total supply of requisite materials will promote no greater growth so long as some other factor is the limiting one.

From these studies the prediction is made that the Jerusalem artichoke may be propagated quite satisfactorily with smaller seed pieces or tubers than is required in the propagation of the potato.

Length of Rest Period of the Tuber of Jerusalem Artichoke (*Helianthus tuberosus* L.)

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ON account of the possibilities of the Jerusalem artichoke tuber as a commercial source of levulose, and also its use in special diets, this plant has assumed a new importance in recent years. Although it is native to North America, is found growing wild in many parts of the United States, has been grown in home gardens for generations, and is extensively grown for stock feed in the northwest, the plant has been the subject of but little investigation in this country, except from the chemical standpoint. The growth of the plant and its response to its environment have been studied very little. Since numerous demands for information are being received, and the demand will doubtless increase, it is desirable to make a brief report of certain studies at this time even though it represents but a single season's work.

There is much interest in the artichoke in certain regions of the lower South where temperatures much below freezing very rarely occur. How will tubers of different varieties grow when planted, if they have never been subjected to a period of cold such as occurs during the rest period in regions farther north?

MATERIALS AND METHODS

In determining the range in the length of the rest period of the tubers, a collection of 145 varieties or forms was used. This material has been collected over a period of years by Dr. D. N. Shoemaker, of the Bureau of Plant Industry, in making a search for all forms of the artichoke that might be of commercial value; and the collection is being maintained at Arlington Farm, Va. Included among the sorts of possible commercial value are about 50 seedlings and others which produce tubers of inferior size or quality but which have been retained for systematic study. The writer is indebted to Dr. Shoemaker for making this collection of material available for the studies upon rest period.

The tubers were harvested the last week in November, about three weeks after the death of the tops, after several frosts, but before any freezing of the soil had occurred; then left in the field, covered with soil for a few days until they could be planted. Twenty tubers of each variety or strain were planted in a single row in soil in greenhouse benches on Dec. 1, 1930. The rows were 6 inches apart and the tubers were slightly covered with soil so that the sprouts would be evident as soon as they emerged from the bud. The soil was kept moist and the house temperature maintained at 60 to 65 degrees F. at night and 70 to 75 degrees F. during the day through the winter and early spring. Toward the end of the period

it was impossible to avoid much higher temperatures on warm days.

Beginning on Jan. 3, 1931, when the first sprouts appeared, each lot of tubers was carefully observed at 4- or 5-day intervals, and the number of tubers from which leaves had appeared, was recorded.

As soon as all the tubers in one lot showed top growth, they were removed from the bench and discarded to avoid shading and crowding of the lots showing smaller growth.

RESULTS

There is a surprisingly long rest period of the tubers of most varieties included in this study. Whereas the first sprout appeared in 2 lots at 31 days and in 3 lots at 40 days, 21 lots showed no sprouts until the 94th day and 10 lots no sprouts for 172 days. One lot showed its first sprout after 200 days, or nearly 7 months.

However, the appearance of the first sprout in a lot of tubers must be considered a poor index of the length of rest period, because certain samples showed 1 or 2 sprouts at a comparatively early date, and not another one for as long as 2 months. In several extreme instances, samples showed one additional sprouting tuber at approximately week or 10-day intervals, requiring as long as 4 months for the remaining tubers to grow, after the first one had sprouted. In this discussion the length of the rest period will be measured arbitrarily by the time required for sprouting of 50 per cent of the tubers in a lot.

In general, the lots which produced the first sprouts early, showed additional sprouting tubers in fairly rapid succession and reached the "50 per cent sprouted" or "all sprouted" stage at a correspondingly early date. Considering 90 lots, of which all tubers grew, the coefficient of correlation between time of first sprout and time of "all sprouting" was $.612 \pm .042$. The coefficient of regression shows a delay of .85 day in reaching the 100 per cent sprouting stage, for each day delay in appearance of the first sprout.

Considering the 90 strains in which all sound tubers had produced sprouts at the termination of the study on July 13, the mean time required for the appearance of the first sprout was 87 ± 2.4 days; 50 per cent had sprouted in 120 days and all tubers had produced sprouts in 155 ± 1.84 days. All tubers in one lot had sprouted in 87 days. There were 55 strains in which not all of the tubers had produced sprouts, but 50 per cent or more had sprouted in each lot.

Considering the entire 145 lots, the mean time required for the appearance of the first sprout was 85 ± 2.1 days; and 50 per cent of the tubers in each lot had sprouted in 130 ± 1.9 days. The time for "50 per cent sprouting" varied from 54 to 200 days. Extrapolation of this growth line gives an approximate mean time of 175 days required for all tubers in each lot to grow.

On account of the variation in time elapsed between the sprouting of the first or second sprouting tuber and the growth of the remaining tubers in individual lots, the time of the first sprout and of the sprouting of the last tuber would both be misleading indices of length of rest period. The time required for sprouting of 50 per

TABLE I—LENGTH OF REST PERIOD OF SIX HIGH-YIELDING VARIETIES OF JERUSALEM ARTICHOKE

Accession No.	Test No.	Days from Planting		
		1st Sprout	50 Per cent Sprouting	100 Per cent Sprouted
27007.....	107	79	135	—
26724.....	133	121	160	188
27574.....	134	79	107	142
27218.....	135	172	180	—
27585.....	136	150	160	—
27082.....	140	150	180	—

cent of the tubers in a lot is a better index. Occasional extremely late-sprouting variants within certain strains make it undesirable to use "100 per cent sprouting" as a comparative index. Furthermore, toward the end of the period of observation excessive day temperatures in the greenhouse and the rotting of some tubers rendered questionable the value of the time for "100 per cent sprouting" as a basis of accurate comparison.

The above figures are of interest only in showing the wide range in behavior within a wide range of forms of the Jerusalem artichoke. They do not, of course, describe the behavior of an individual variety, nor even of modal types. When the number of strains beginning to sprout is plotted against the number of days at 15-day intervals, a curve with well defined double maxima is obtained. A bi-modal curve is obtained also when "50 per cent sprouting" is plotted against time, indicating the presence of two rather distinct groups within the collection considered here. One peak of first sprouting occurred at 53 days and another at 97 days. The corresponding peaks of "50 per cent sprouting" occurred at 127 and 172 days.

Table I presents data upon individual lots representing the commercially most promising varieties in the collection. Table II presents similar data for a number of apparently worthless sorts that were dropped from the trials in 1931. In these few data there is no apparent correlation between yielding capacity and length of rest period, although the rest period of most of the good varieties is relatively long, 5 to 6 months if the tubers are not subjected to low temperature.

The detailed rest period data were studied with reference to the growing plants in the field early in October 1931, to determine if growth habit, vegetative characters, time of flowering, or appearance of flowers are similar among the various lots showing a simi-

lar length of rest period. In general, a very wide range of forms of plant were represented in any group of varieties of similar rest period. It was noted, however, that a very large proportion of the varieties of relatively short rest period were seedlings of Blanc Ameliore grown and selected by Doctor Shoemaker, or seedlings of

TABLE II—LENGTH OF REST PERIOD OF TEN COMMERCIALY WORTHLESS VARIETIES OF JERUSALEM ARTICHOKE

Accession No.	Test No.	Days from Planting		
		1st Sprout	50 Per cent Sprouting	100 Per cent Sprouted
27586.....	7	129	155	172
26720.....	9	47	160	172
26724-1.....	10	172	172	—
26724-2.....	11	129	138	—
26724-3.....	12	150	180	—
26724-4.....	13	40	114	172
26724-5.....	14	142	172	—
26724-9.....	18	172	200	—
26723-2.....	20	64	114	—
26723-3.....	21	59	87	150

unknown parentage obtained from a French seed firm. It should not be concluded from these meager data that there is a relation between the age of the clonal variety and rest period, for the tubers of the longest rest period observed are from seedlings, and some of the earliest sprouting sorts are certainly relatively old.

There is a group of three lots in the collection which were obtained from widely different sources but which appear identical in the field. Because of their great similarity and reports concerning their origin, they are all believed to have come from a single stock. The rest period of these three lots is also apparently identical. Two other lots, apparently identical, attained 50 per cent sprouting in 160 and 180 days, respectively.

Twenty different lots obtained from widely separated regions appeared much like Blanc Ameliore but 5 of this number exhibited rest periods so much shorter or longer than Blanc Ameliore that they are probably distinct from that variety. These few observations suggest the importance and value of length of rest period as an aid to identification.

Extensive studies are now in progress in the Division of Horticultural Crops and Diseases upon the nature of the rest period of the Jerusalem artichoke tuber, and methods of breaking the rest period. These matters may be of considerable practical importance in regions where mild winter temperatures may be insufficient to shorten the rest period, and where satisfactory growing weather prevails during certain winter months.

Apical Dominance in the Tuber of the Jerusalem Artichoke (*Helianthus tuberosus* L.)

By VICTOR R. BOSWELL, *U. S. Department of Agriculture, Washington, D. C.*

IT has been commonly observed in the field that the number of stalks of Jerusalem artichoke per hill may vary enormously. The question has arisen as to whether the very numerous sprouts per hill were the result of some exhaustion or injury of the seed piece which gave rise to multiple sprouting, or whether multiple sprouting normally occurs. The present brief study was not designed so as to answer this question adequately, but it does give some interesting information on the sprouting habit of the tuber.

METHODS

One hundred freshly dug tubers of the White Improved variety, weighing approximately 40 gms. each were placed on moist sand in a greenhouse bench and covered with 4 inches of moist peat moss on April 8, 1931. As soon as a few sprouts emerged from the peat, all tubers were carefully taken up and the roots removed without breaking off any sprouts. This tedious procedure was necessary in order to observe the exact point from which each sprout originated. The sprouts were removed and the following data recorded: Number of branches or protuberances of each tuber; number of sprouts arising from apical, middle and basal buds of each tuber; the total weight of sprouts from each of the three regions of all tubers. Then the tubers were replanted in the greenhouse as before. As successive crops of sprouts began to appear above the peat covering, the tubers were taken up and data recorded as described above. Figures for five successive crops of sprouts were obtained.

The artichoke tuber of 25 to 30 gms. or more in size is rarely smooth or symmetrical in this variety. These specimens in general were quite "knobby" or distinctly branched. All sprouts arising from the easily recognized terminal bud of a branch (or tuber) or within a radius of 5 to 6 mm. from the center of that bud, were considered as apical sprouts. Buds arising from approximately the basal third of the entire tuber (exclusive of branches which might be present on the basal third) were considered as basal sprouts. All other sprouts were classed as medial.

RESULTS

The most striking observation in these studies was that each branch on the tuber behaves more or less independently of other branches and the main tuber apex. This is true even of very slight-

ly developed branches which appear only as slight swellings on the large tuber, and which are terminated by a large bud and accompanying lateral buds. Only small tubers are apparently without branches.

TABLE I—NUMBER, WEIGHT, AND POSITION OF FIVE SUCCESSIVE CROPS OF SPROUTS ON LARGE JERUSALEM ARTICHOKE TUBERS

Date Sprouts Removed	Basis of Com- parison	Number of Sprouts			Weight of Sprouts		
		Apical	Medial	Basal	Apical (Gms.)	Medial (Gms.)	Basal (Gms.)
4-18-31	Per tuber	3.65±.16	1.53±.08	.07	1.88	.53	.04
	Per branch	1.03	.43	.02	.53	.15	.01
	Per cent total	69.50	29.20	1.30	76.70	21.80	1.50
	Per sprout				.515	.346	.570
4-28-31	Per tuber	5.68±.20	2.20±.15	.13	1.23	.40	.02
	Per branch	1.60	.62	.04	.35	.11	.006
	Per cent total	70.90	27.50	1.60	74.70	24.01	1.29
	Per sprout				.217	.182	.154.
5-9-31	Per tuber	5.39±.23	2.45±.13	.12	1.08	.56	.02
	Per branch	1.52	.69	.04	.31	.16	.006
	Per cent total	67.80	30.70	1.50	65.20	33.60	1.20
	Per sprout				.200	.228	.167
5-26-31	Per tuber	5.28±.28	2.75±.18	.31	.85	.37	.08
	Per branch	1.49	.78	.09	.24	.11	.02
	Per cent total	63.30	32.70	4.00	65.20	28.60	6.20
	Per sprout				.161	.134	.251
6-12-31	Per tuber	1.59±.16	1.07±.13	.10	.26	.21	.03
	Per branch	.56	.38	.04	.09	.07	.01
	Per cent total	57.50	38.70	3.80	52.70	42.10	5.20
	Per sprout				.163	.196	.300
Total of five crops		21.59	10.00	.73	5.30	2.07	.19
		6.50	3.01	.22	1.60	.62	.05
		66.70	30.90	2.40	70.10	27.02	2.88
					.246	.207	.260

In the first as well as successive crops of sprouts, sprouting was not confined to branches of any definite region of the total tuber. Multi-branched tubers produced multiple sprouts from the first but not all branches produced sprouts. In the first crop there was no correlation between branch number and apical sprout number, the value of r being $-.008 \pm .067$, and for medial sprouts r was $+.007 \pm .066$. Considering these large tubers as a unit, it could hardly be said that apical dominance was strongly in evidence at any time in these studies. It is conceivable that under certain conditions sprouts on one branch might be dominant over those of other branches, but this condition has not been observed. Furthermore,

the apparently general occurrence of multiple stalks per hill in the field suggests that there is but little dominance of one branch over another.

The number and weight of sprouts per tuber and per branch are shown for each crop of sprouts in Table I. It will be noted that the number of apical sprouts in the second, third and fourth crops is practically constant and is about 50 per cent higher than in the first; in the fifth crop it drops to less than half the number of the first. The medial sprout number in the second crop is about 50 per cent greater than in the first and in the third and fourth crops, still further increases are noted, in contrast to the behavior of the apical sprouts. Basal sprouts were very few in all cases, although there is seen a tendency to increase in number in the first four crops. The total weight of apical sprouts decreased in successive crops, while the total weight of medial sprouts increased, although sprout numbers of each were not materially different in the second, third, and fourth crops. The size of individual apical sprouts decreased in successive crops, while medial sprout weights varied in no consistent direction after the first crop.

The value of the sprout weights may be questioned since temperature was not controlled in this study and the data may not have been taken at exactly comparable stages of development. However, the weights of apical and medial sprouts in the same crop may be compared with confidence. It will be seen in Table I that the proportion of medial sprouts gradually increases and apical sprouts decreases in successive crops. This is true for both sprout number and sprout weight per tuber. Thus it appears that there is a small negative correlation between proportions of apical and medial sprouts; and that it might be concluded that apical sprouts gradually decrease in their partial dominance over medial sprouts.

In the fifth crop 38 per cent of the tubers produced no apical sprouts while 48 per cent produced no medial sprouts. If there is a loss of dominance of the apical sprouts with successive sprout removal, one would expect the medial sprout number to increase appreciably when the apical sprouts failed to develop on certain tubers. However, only 45 per cent of the tubers without apical sprouts developed medial sprouts and most of these developed but one sprout. Of the tubers with no medial sprouts only 57 per cent developed apical sprouts. Considering the entire lot of tubers (the fifth crop of sprouts) the coefficient of correlation between apical and medial sprout number was $+0.084 \pm .088$, which amounts to no correlation at all. In the fourth crop of sprouts the correlation was $+0.239 \pm .066$ which is very small and barely significant. No correlation existed in any of the first three crops.

As a result of successive sprout removal the capacity for producing numbers of medial sprouts apparently changes to about the same extent as that for producing apical sprouts. The weight of medial sprouts represented only 21.8 per cent of the first crop of sprouts while it composed 42.1 per cent of the weight of the fifth

crop. Basal sprouts were so few in number and made up such a small proportion of the total sprout weight as to be of little importance, although the proportions of both number and weight per tuber increased with successive crops. Thus there appears to be a slight loss of apical dominance with successive sprout removal.

TABLE II—CORRELATIONS BETWEEN NUMBERS OF APICAL AND MEDIAL SPROUTS AND NUMBER OF BRANCHES OF THE JERUSALEM ARTICHOKE TUBER. FIVE SUCCESSIVE CROPS OF SPROUTS

Dates Sprouts Removed	Values Compared	Number Branches and Number Apical Sprouts per Tuber	Number Branches and Number Medial Sprouts per Tuber	Number Apical and Number Medial Sprouts per Tuber
4-18-31		$-.008 \pm .067$	$+.007 \pm .066$	$+.024 \pm .066$
4-28-31		$+.371 \pm .060$	$-.120 \pm .069$	$+.066 \pm .069$
5-9-31		$+.432 \pm .057$	$-.062 \pm .069$	$-.050 \pm .069$
5-26-31		$+.711 \pm .055$	$+.247 \pm .070$	$+.239 \pm .066$
6-12-31		$+.487 \pm .069$	$+.300 \pm .080$	$+.084 \pm .088$

As mentioned above, there was no correlation between number of sprouts and number of branches per tuber in the first crop. Unbranched tubers showed from 1 to 5 apical sprouts, and in contrast, 3-branched tubers produced from 0 to 10, and 5-branched tubers from 0 to 12 sprouts. Obviously many branches were without apical sprouts in this crop. In successive crops there was a progressively greater correlation between sprout number and branch number, as shown in Table II. It is hardly probable that this increasing tendency for many-branched tubers to bear more sprouts in successive crops indicates a loss of dominance of the first sprouts over other buds because the results of sprout removal were quite variable. In many cases 3 or 4 sprouts would arise from buds on the base of a sprout previously broken off close to the tuber; while on the same tuber another branch would show no sprout replacement. The correlation is more probably the result merely of increased sprout numbers on individual branches.

The more or less independent multiple apices of multiple-branched tubers have presented some unforeseen difficulties in this preliminary study. In further studying this problem it is planned to work with single apex tubers, and to record completely the sprout and bud behavior of each branch of each multiple-branched tuber.

CONCLUSION

Individual branches of multiple-branched tubers are apparently dominant over no other branches. A partial apical dominance apparently exists within the individual branch since approximately twice as many apical sprouts as medial and basal sprouts were produced in the first three crops. There is but a slight loss of the partial apical dominance after the removal of three to four crops of sprouts.

Results of Paper Mulch Experiments With Vegetable Crops

By H. C. THOMPSON and HANS PLATENIUS, *Cornell University, Ithaca, N. Y.*

THE experiments reported here were carried on at Ithaca, New York, on a Dunkirk sandy loam soil during the four years 1928 to 1931. Six crops, namely, beets, beans, cabbage, tomatoes, peppers, and muskmelons were included in the experiment. Peppers and muskmelons were in the experiment only three years, 1929-1931.

TABLE I—AVERAGE YIELD PER ACRE OF SIX VEGETABLE CROPS IN PAPER-MULCH TRIALS (1928-31)

Crop	Cultivated (Pounds)	Mulched (Pounds)	Per cent Increase or Decrease	Odds
Beets.....	37,149	35,302	— 5	30:1
Beans.....	6,449	7,240	12	None
Cabbage.....	23,952	23,711	— 1	None
Tomatoes.....	26,178	30,749	17	66:1
Peppers.....	3,585	5,625	57	87:1
Muskmelons.....	16,493	18,730	13	22:1

The crops were grown in the usual manner and good strains of standard varieties were used in all cases. Seeds of beets and beans were planted in place in the field as early as the weather conditions were favorable. Seeds of the other crops were started in the greenhouse at the proper time and the plants were set in the field as early as it was considered safe. Mulch paper was compared with clean, shallow cultivation and the treatments were in triplicate. Each plot consisted of five rows with the exception of the muskmelon plots which contained three rows each. The rows of beets, beans, cabbage, and peppers were 20 feet long, those of tomatoes 30 feet, and those of muskmelons 75 feet.

The paper was applied between the rows of all crops except muskmelons. The muskmelon plants were planted through openings made in the center of the strips of paper 3 feet wide. The rows of muskmelons were 5 feet apart so that only three-fifths of the land was covered.

The average yields of the marketable portion of the crops are given in Table I. This table shows also the percentage increase or decrease due to the mulch and the odds of significance calculated by Student's Method.

The data in Table I show that the mulched plots of beets produced a lower yield than the cultivated plots, but the odds indicate that the difference is barely significant. The average yield of beets on the cultivated plots was higher every year than on the comparable mulched plots. With beans the increase in yield is not

statistically significant, although the average yield was higher on the mulched plots every year. The average yield of cabbage was practically the same under the two treatments, but the cultivated plots produced the larger yield three years out of four. With tomatoes the 17 per cent larger yield on the mulched plots is statistically significant. In three years of heavy yields the mulched plots produced a considerably larger yield than the cultivated plots while

TABLE II—AVERAGE YIELD PER ACRE OF EARLY PORTION OF CROP IN PAPER-MULCH EXPERIMENTS

Crop	Cultivated (Pounds)	Mulched (Pounds)	Per cent Increase or Decrease	Odds
Beans.....	1,604	1,770	10	None
Cabbage.....	8,784	8,400	— 4	None
Tomatoes.....	3,830	4,936	30	195:1
Peppers.....	1,563	2,344	50	89:1
Muskmelons.....	1,409	4,207	200	138:1

in 1930, a year of very small yields, the cultivated plots produced the larger yield by nearly 12 per cent. The mulched plots of peppers produced 57 per cent greater yield than the cultivated plots in spite of the fact that the yield in 1931 was very low and nearly the same under the two treatments. The increase in yield of peppers on the mulched plots is statistically significant. The yield of muskmelons was very high during the dry seasons of 1930 and 1931 and low in the wet season of 1929. In 1929 and in 1931 the yield on the mulched plots was considerably greater than on the cultivated plots, but in 1930 the slight difference was in favor of cultivation. The increase of 13 per cent is not statistically significant.

EFFECT OF PAPER MULCH² ON EARLINESS

With the crops used in this experiment, earliness is of considerable importance since the price usually is comparatively high during the early part of the harvest season. To determine the effect of mulch paper on earliness, the yields during the first part of the season have been computed and the data are given in Table II. With beans and cabbage the early yield includes the first harvest, while with tomatoes, peppers, and muskmelons the early yield includes the portion of the crop harvested during the first two weeks. The price received for the early portion of the crop averaged much higher than that received for the crop as a whole. In the case of tomatoes the early portion of the crop sold for about four times as much per pound as the late portion.

The data in Table II show that mulch paper markedly increased the early yield of tomatoes, peppers, and muskmelons, the increase for muskmelons being 200 per cent. The slight increase in early yield of beans and the decrease of cabbage on the mulched plots are not significant. Due largely to increasing the early yield, mulch paper was profitable with tomatoes, peppers, and muskmelons.

EFFECTS OF PAPER MULCH ON SOIL TEMPERATURE

Several investigators have shown that black unperforated paper applied to the soil increases the temperature over that of the uncovered soil. In some cases the increase was several degrees. In the experiments at Ithaca the temperature of the soil at depths of 3 and 6 inches was obtained three times a day during three growing seasons and a continuous record was obtained in 1931. The data

TABLE III—COMPARISON OF EFFECT OF CULTIVATION AND PAPER MULCH ON SOIL-MOISTURE CONSERVATION

Percentage Moisture, Dry-weight Basis										
Beets—1930			Tomatoes—1930					Peppers—1931		
Date	0 to 5 ins.		Date	0 to 5 ins.		5 to 10 ins.		Date	0 to 7 ins.	
	C.	M.		C.	M.	C.	M.		C.	M.
5/8	12.0	12.9	6/13	12.5	13.7	—	—	6/17	11.4	12.8
5/21	15.1	15.7	6/27	11.8	13.4	—	—	7/2	8.5	10.8
6/2	12.9	15.0	7/5	10.9	12.6	12.0	12.1	7/14	12.7	10.6
6/13	13.3	14.8	7/18	10.8	12.1	12.1	12.6	7/28	8.6	9.4
6/27	10.6	12.1	7/31	8.6	10.1	9.1	10.1	8/11	10.2	15.3
7/16	13.4	13.7	8/15	5.9	5.3	7.1	7.0	—	—	—
—	—	—	9/4	11.2	12.5	10.6	11.7	—	—	—

show a slight increase in temperature in favor of the mulch, but at times there was very little difference. In general, the greatest difference was in the morning, but the mulched soil had the higher temperature throughout the night. In other words, the paper decreased the loss of heat during the night and this probably was advantageous to the growing crops during the cooler parts of the growing season. This may account for the fact that the warm-season crops were benefited more by the paper than were the other crops.

EFFECT OF PAPER MULCH ON SOIL MOISTURE

In order to determine the effects of the mulch paper on soil moisture, soil samples were taken at intervals of about two weeks during the seasons of 1930 and 1931. One sample comprising 6 borings was taken from each of the three replicate plots of both treatments. Moisture was determined on 100-gram samples by drying at 100 degrees C. for 24 hours. In 1930 samples were taken at two depths, one from 0 to 5 inches and the second from 5 to 10 inches, while in 1931 samples were taken from one depth only, namely, from 0 to 7 inches. The data on soil moisture are given in Table III. The soil of the beet plots was sampled in 1930 and 1931, that of the tomato plots in 1930, and of the pepper plots in 1931.

The data in Table III show that the mulch paper conserved more moisture than good clean cultivation. In all of the determinations, except three, the mulched soil had considerably higher moisture content than the cultivated soil, and with two of the exceptions the

difference was slight. In the third case the sampling was done four days after a hard rain. During such rains more water runs off of the mulched plots than from the cultivated plots. The results reported here are in agreement with those obtained by other workers.

TABLE IV—COMPARISON OF QUANTITY OF NITRATE NITROGEN IN CULTIVATED AND MULCHED SOIL

Nitrate Nitrogen in Parts per Million of Soil										
Beet Plots—1930			Tomato Plots—1930					Pepper Plots—1931		
Date	0 to 5 ins.		Date	0 to 5 ins.		5 to 10 ins.		Date	0 to 7 ins.	
	C.	M.		C.	M.	C.	M.		C.	M.
5/8	46	33	6/13	36	56	—	—	6/17	13	23
5/21	30	54	6/27	14	80	—	—	7/2	27	44
6/2	41	46	7/5	20	80	24	63	7/14	21	42
6/13	21	30	7/18	29	77	28	54	7/28	12	24
6/27	4	3	7/31	20	49	16	51	8/11	4	15
7/16	2	2	8/15	27	64	15	56	—	—	—
—	—	—	9/4	21	38	20	25	—	—	—

EFFECT OF PAPER MULCH ON NITRIFICATION

One of the advantages claimed for mulch paper is increased nitrification due to moisture conservation and higher soil temperature. In order to determine the effects of mulch paper on nitrification, nitrate nitrogen determinations were made on the soil samples taken for soil-moisture studies. The method used was the official phenoldisulfonic acid method. The data on these determinations are given in Table IV.

Nitrification was more rapid in the mulched soil than in the cultivated soil as is shown by the quantity of nitrate nitrogen found under the two treatments. Increased nitrification in the mulched soil is probably related to greater moisture content and to the slightly higher temperature of this soil as compared with the unmulched soil.

Correlation Studies Between Size of Crown and Yields of Asparagus

By E. S. HABER, *Iowa State College, Ames, Iowa*

ABSTRACT

The complete paper will be published in the *Journal of Agricultural Research*.

UNDER the conditions of the experiment, significant correlations exist in male asparagus plants between weight of one-year-old crowns, when planted, and the number of spears and total weight of spears produced during the first three cutting seasons. With female crowns no significant correlation exists between the same variables.

The Effect of Length of Cutting Season on Yields of Asparagus

By E. S. HABER, *Iowa State College, Ames, Iowa*

ABSTRACT

The complete paper will be published in the Journal of Agricultural Research.

REPLICATED plots of asparagus were cut for the first three seasons of cutting up to May 1, May 15, June 1, June 15, July 1, and July 15. There was an increase in production for 1931 in each successive series except of rows cut until July 15. Rows cut until July 15 in the third year did not yield as much as rows cut until June 15, although 13 more cuttings were made. Rows cut until July 15 did not yield as well as those rows cut until July 1, although 7 more cuttings were made. The rows cut until July 1 showed no decrease but the increase over rows cut a shorter period, though significant, are not highly significant and future records may disclose that this date is entirely too long to harvest. Even cutting to June 15, after several more years of the same treatment, may result in a rapid decline in yield and shorten the life of the planting.

Anthesis and Pollination of the Capsicums

By A. T. ERWIN, *Iowa State College, Ames, Ia.*

ABSTRACT

This paper will appear in the bulletin series of the Iowa Agricultural Experiment Station.

THE period of anthesis in the Capsicums was found to be comparatively short. The major portion of the blossoms open during the first 2 hours after sunrise. Dehiscence follows the opening of the flowers rather closely. There are two types of styles. In the long podded primitive types, the style is longer than the stamens and does not favor self fertilization. In the varieties of the large blocky type, the style is short and stout, usually shorter than the stamens. Records secured by the author indicate that the Capsicums are self fertile.

The Capsicums were found to produce nectar bearing flowers and under favorable conditions are visited by numerous pollen bearing insects. Seed saved from open pollination from plants adjacent to other varieties show many "splits." The author concludes that the Capsicums are both self and cross fertile.

Carrot Seed Germination

By H. A. BORTHWICK, *University of California, Davis, Calif.*

THE poor germination of carrot seed is one of the most important problems of the California vegetable seedsmen. While satisfactory seed will germinate 75 per cent or higher, many lots of seed germinate well below 70 per cent; and the germination appears, in general, to be poorer in some years than in others. Investigations already started may show in a few years what conditions cause the production of poor seed. Meanwhile, it has seemed desirable to study certain flowering and fruiting habits of the carrot in order to determine their bearing on the quality of seed produced. This preliminary study is reported in the following pages.

BRANCHING HABIT OF THE CARROT

The flowers of carrot are produced in compound umbels borne terminally on the branches. This habit of flowering permits one to segregate the inflorescences into several groups according to their position on the plant, as may be most readily understood by reference to Fig 1. The main axis of the plant terminates in a compound umbel which may be called the umbel of the first order. From the main axis of this particular plant arise 13 side branches, each terminating in a compound umbel. As these umbels are borne on side branches of the main axis, we may assign them to the second order. Each of the 13 branches of this plant also bears 2 to 7 side branches, terminating in umbels of the third order. In the particular plant shown in the diagram of Fig. 1, only 3 orders of umbels produced seed. Frequently, however, a large number of fourth order umbels are formed, and, in a few cases, seed-bearing umbels of fifth and sixth orders have been observed.

This habit of growth results in an early and definite establishment of the frame-work on which the plant is to bear seed. Investigation has shown (1) that well-developed primordia of both first and second order umbels may be found as early as the middle of March in carrots that were reset in late December. As the second order umbels are already differentiated at this time, the number of nodes on each second order branch is also determined, and therefore the maximum number of third order umbels which the plant can produce is likewise established. Over 90 per cent of the seed crop is usually produced in the first 3 orders of umbels, as will be brought out more fully in a later paragraph. Since the number of first, second, and third order umbels is established as early as the middle of March, the position in which the greater part of the crop is to be borne is evidently determined very early and is not much influenced by conditions arising later in the season.

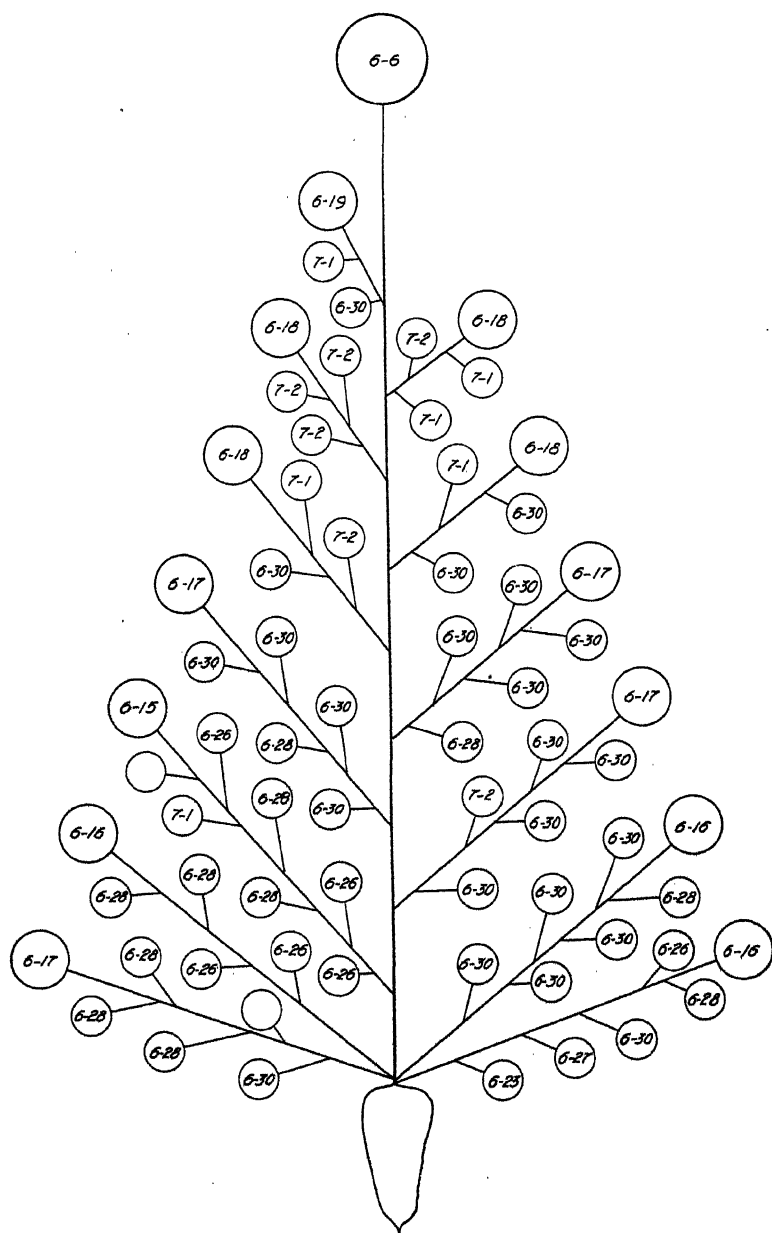


FIG. 1. Diagram of a carrot plant showing position of umbels. Circles of similar size represent umbels of the same order. Figures within the circles are the dates of petal fall.

The growth habit of carrots makes impossible certain practices followed with various other vegetable seed crops. Beets, for example, produce their flowers in indeterminate spikes, the length and number of flowers of which are influenced to a certain extent by conditions during the flowering period; and so the main axis is frequently cut back in order to force the lower laterals to greater development and thus keep the plants closer to the ground. Such a practice would not be applicable to the carrot because of its habit of growth. Cutting the main axis back would not increase the production of flowers on second order branches but would only stimulate the production of umbels of higher orders, with a consequent delay in flowering.

TABLE I—AVERAGE NUMBER OF UMBELS PER PLANT OF EACH ORDER PRODUCING SEED

Source of Data	Umbels of Each Order			
	1	2	3	4
10 Chantenay plants.....	1	15	53	13
10 Chantenay plants.....	1	12	48	42
48 Danvers Half Long plants.....	1	14	46	23

TIME OF FLOWERING

Because of the habit of growth in carrot, anthesis is not a continuous process in any one plant but proceeds rather by waves, each wave corresponding to one order of umbels. As petal fall almost coincides with fertilization and is a conspicuous and definite stage in the process of anthesis, it was chosen as a point of reference for comparing the dates of flowering of umbels of different orders. In the plant represented in Fig. 1, for example, the majority of the flowers of the first order umbel dropped their petals on June 6. No more flowers on this plant lost their petals until June 15. Between June 15 and 19, all 13 of the second order umbels reached this stage. No flowers lost their petals between June 19 and 23, but between June 23 and July 2, all the third order umbels attained this stage of development.

Records similar to those given in Fig. 1 were made for 10 different Chantenay plants. These data showed that the second order umbels opened, on the average, 9 days after the first order; the third order, 11 days after the second; and the fourth order, 13 days later than the third. Fertilization of the flowers of the second, third, and fourth order umbels took place, therefore, about 9, 20, and 33 days, respectively, after fertilization of those of the first order umbel. Evidently, then, anthesis in any one plant is an intermittent process, frequently extending well over a month.

NUMBER OF UMBELS OF EACH ORDER

Data were collected from several lots of carrots to determine the average number of umbels of each order. These figures are presented in Table I.

One notes that in each of the first three orders, the number of umbels is about the same in all three lots. In the fourth order, how-

ever, much more variability is found, a fact in harmony with what has been said concerning the time and manner of differentiation of umbel primordia.

WEIGHT OF SEED BY ORDERS

In order to get an idea of the relative amount of seed produced by each of the different orders of umbels, lots of plants from commercial fields were harvested by orders. The results were, of course, somewhat variable. Table II, however, shows approximately what is to be expected under usual growing conditions.

TABLE II—YIELD OF CARROT SEED BY ORDERS, EXPRESSED AS PERCENTAGE OF TOTAL YIELD

Source of Data	Order			
	1	2	3	4
10 Chantenay plants.....	3.9	46.7	47.2	2.2
60 Danvers plants.....	4.8	40.9	49.6	4.7
48 Danvers plants.....	4.1	38.0	51.2	6.7

Evidently the seed crop of carrot is about equally divided between the first two and the last two orders of umbels, and the first three orders produce about 95 per cent of the crop.

QUALITY OF CARROT SEED OF DIFFERENT ORDERS

In a plant such as carrot in which, as a consequence of its habit of growth, the inflorescences can be grouped into definite orders with pronounced differences in time of fertilization and in other characters as well, it is interesting to determine whether or not there are any corresponding differences in quality of seed produced. Plants were therefore harvested by orders in 1929, 1930, and 1931, and comparative germination tests were run, according to official standard methods, on seed from each order. The results from the three years are shown in Table III. The data for 1929 are based on the mean of twenty-one 10-plant samples of French Forcing carrots grown in a commercial planting near Clarksburg, California. The 1930 data are based on 10 Chantenay plants grown at Davis. Separate germination tests were made of the seed from each umbel of these 10 plants, and the data presented in Table III represent the mean percentage germination of all umbels of each order. In 1931, data were taken from six plots of 10 carrots each in a commercial planting of Danvers Half Long, grown near Clarksburg.

One notes that in all three years the seed produced by the first two orders of umbels was somewhat better than that produced by higher orders. In 1930, when the germination of all orders was exceptionally good, a difference still appeared between the germination of the first two and the last two orders. Although the means of orders 2 and 3 differed by only 5.1 per cent, the probable error of their difference was only $\pm .47$, a fact which indicates that the difference is

significant. In a year like 1929, when germination was much lower, the difference is more striking.

TABLE III—GERMINATION OF CARROT SEED FROM UMBELS OF DIFFERENT ORDERS

Year	Per cent Germination			
	Order 1	Order 2	Order 3	Order 4
1929.....	73	67	54	—
1930.....	94	93	88	85
1931.....	75	74	65	69

WHY DO CARROT SEEDS FAIL TO GERMINATE

Germination tests of carrot seeds are usually run for about 2 weeks. Most of the seeds that germinate during this time do so in the first week; during the second, the number germinating is much smaller. Often, at the end of 2 weeks, most of the ungerminated seeds are still firm and in apparently good condition. A large number of seeds of this type have been split lengthwise and examined with a binocular microscope. Nearly all have a firm endosperm of the usual size. The embryo of such seeds, however, is almost never fully developed and is sometimes so small as to be scarcely visible.

Many of these seeds may eventually germinate if given sufficient time, as shown in unpublished work of Miss Cole (2). She ran a large number of tests for the usual 14-day period; then, instead of discarding the ungerminated seeds, she kept them in the germinator for several months. In 87 lots of seed which she kept in the germinator for an average period of 5 months, she succeeded in raising the mean germination from 60 per cent, at the end of 2 weeks, to 78 per cent at the end of 5 months. The figures indicate that many of the under-developed embryos described above will eventually mature if the seed is kept in the germinator long enough. An important cause of low germination in carrots, therefore, appears to be dormancy resulting from immature embryos.

Investigations for the purpose of improving the yield and quality of carrot seed are being continued. One phase of this work consists of breeding investigations. Most of the breeding work done heretofore has been concerned with quality of the roots, and little attention has been given to those characters, such as seeding habits, which do not express themselves until the second year. A second phase of the work is concerned with the effect of various cultural practices on the size and quality of the seed crop.

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Some Factors Influencing the Reproduction of Shallots

By J. M. JENKINS, JR., and JULIAN C. MILLER, *Louisiana State University, Baton Rouge, La.*

THE shallot, *Allium ascalonicum* Linn., is grown to a limited extent in the United States, chiefly in Louisiana, which ships several hundred cars yearly from the district extending from Baton Rouge down the Mississippi River valley to New Orleans. During the fall and winter of 1930-31 approximately 1,000 cars (including shallots shipped in cars of mixed vegetables) were shipped from this state.

The true shallot, upon reaching maturity, produces bulbs which are dull white in color and which usually weigh up to 15 grams, probably averaging 6 to 9 grams. The bulbs are attached at the base, forming a cluster (or clone) which may consist of from 2 to 20 bulbs.

Little experimental work has been done with shallots up to the present time. Due to their growing importance as a truck crop in Louisiana, it was desired to obtain information on the following points: (1) the influence of length of storage upon subsequent stooling and seeding; (2) the influence of size of bulb planted upon subsequent growth of the plant; (3) the influence of planting date of bulbs upon subsequent growth characters; (4) whether or not there is a difference as to character of stooling and seeding of different strains; and (5) the value of clone selection as a method of isolating desirable strains.

The results given in this paper are from one year's experiments which were begun in the fall of 1930 and are being continued at this time.

Shallot bulbs were held in cold storage at a temperature of 40 degrees F. for periods of 15, 30, and 60 days respectively, and were then planted in the field.

Bulbs stored for 60 days at 40 degrees F. went to seed in 30 days less time than did those not stored, and in 12 to 19 days less time than did those stored for shorter periods of time. It was noted that plants from bulbs stored for 30 to 60 days were less vigorous and made less vegetative growth than did those from bulbs which were not stored, or which were only stored for a short period of time.

That the size of the bulb planted has an effect upon the subsequent growth of the plant can be seen from the results given in Table I.

There was a constant increase in the size of the plants directly proportional to the size of bulb planted. The larger sized bulbs produced more plants per bulb and the plants were also taller and had more leaves than did those from smaller bulbs. It was interesting to note that at maturity the plants grown from the two smallest

sized groups of bulbs weighed on an average from 1½ to 2 pounds, while those from the two largest sized bulbs weighed from 3 to 3½ pounds. Large sized bulbs produced 38 to 58 per cent more seed-stalks than did the smaller bulbs but they also produced twice as many marketable sized plants.

TABLE I—COMPARISON OF PLANTS GROWN FROM BULBS OF DIFFERENT SIZE, 70 DAYS AFTER PLANTING

Weight of Bulb ¹ (Grams)	Ave. No. Plants from Each Bulb	Ave. No. Leaves	Ave. Height of Plants (Inches)
Under 3	2.14	5.6	9.55
3 to 6	3.25	6.6	10.40
6 to 9	4.07	6.9	11.13
9 to 12	5.14	6.4	11.74
12 to 15	6.31	6.2	12.60
Over 15	7.40	6.3	13.06

¹Seventy bulbs of each size were planted.

Shallot bulbs were planted at intervals of 15 days from October 29, 1930 until January 9, 1931. Those planted in October, November, and the first part of December produced marketable sized plants in January and February, while those planted in January never reached a marketable size. This was due to the fact that seed-stalks began to develop on March 16, before the plants reached a height of 6 inches, and shortly afterward they began dying down. It was noted that all of the plants went to seed within eleven days of each other (March 5 to 16). Those planted in October showed seed-stalks in 127 days, while those planted in January developed seed-stalks in 66 days.

Three strains of shallots were planted for comparison of growth characters. The chief difference observed was in the length of time before seed-stalks appeared and the number of seed-stalks produced. Strain No. 1 went to seed in 99 days but the other two strains did not seed until 28 days later. Strains Nos. 1 and 3 went to seed 100 per cent, but strain No. 2 produced 98.3 per cent seed-stalks. Strain No. 2 besides developing less seed-stalks also produced more vigorous and larger plants than did the other two strains, and the mature bulbs were larger.

Forty clones, or clusters, consisting of from 5 to 15 bulbs were separated and planted in individual rows. Observations were made of the performance of each clone. It was noted that all of the plants from any one clone went to seed within two or three days of each other, but different clones varied considerably in the length of time before seed stalks developed. Plants from clones Nos. 27A and 28A produced seed-stalks in 92 days, while clone 5A did not seed for 140 days, a difference of 48 days. All the plants from clones Nos. 29A and 31A were badly diseased, being infected with *Botrytis cinerea*, but plants from other clones appeared to be free from disease and were healthy and vigorous.

Seven plants from one clone emerged from the ground, but all died before developing further. Besides the differences already noted above it was seen that plants from different clones also showed considerable difference in size of plant, color of foliage, and number of bulbs developed.

The Carbohydrate and Nitrogen Metabolism in Celery as Related to Premature Seeding

By H. PLATENIUS, *Cornell University, Ithaca, N. Y.*

ABSTRACT

The complete paper is to appear as a memoir from Cornell University Agricultural Experiment Station.

THE carbohydrate and nitrogen metabolism was studied in celery plants in connection with the tendency to form seed stalks. At frequent intervals, samples were taken from plants which during the early stage of growth had received different temperature treatments. It was concluded that the composition of the plants, particularly the carbohydrate-nitrogen ratio, has no casual relation to seed stalk development at a later stage. Changes in chemical composition associated with premature seeding of celery must be considered as the effect rather than the cause of a change in the type of growth. The data throw some light on the carbohydrate and nitrogen metabolism of normal plants.

Some Factors Affecting the Color and Thickness of Onion Scales

By J. E. KNOTT, *Cornell University, Ithaca, N. Y.*

GROWERS experience difficulty in raising onions which will meet market requirements on certain muck deposits in New York. The onions develop well as far as size and yields are concerned, but fail to show the degree of pigmentation that the buyers demand. The outer bulb scales are thin and shed readily as the onions pass over the topper and grader. Not only are these dry scales thin, but they are just faintly colored. If these pale yellow or greenish bulbs are held in storage for some time a fair degree of pigmentation will show in the next scales which dry. However, much of the onion crop is not stored by the growers, but sold to dealers who object to buying these pale-colored bulbs. Thus, there is often 25 to 50 per cent of the crop which must be thrown away or sold at a distinct loss.

Not all of the muck in any given area produces poorly colored onions nor do all the bulbs in a field show poor pigmentation to the same degree.

Many ideas are held by growers as to the cause, but some of these are quite contradictory. A few of the beliefs which appeared worthy of further study are: better color resulting on muck longer under cultivation, if well fertilized; better color on wetter muck; better color following well fertilized and sprayed celery or potatoes; and better color when the oil-bordeaux spray is used for onion maggot control. The problem has been attacked in several different ways, a preliminary report on one of which is given here.

Muck was obtained at Canastota from an area which produces poorly colored onions, and from a place nearby where the color is good. These are referred to hereafter as poor- or good-color muck. Each lot was well mixed and placed in wooden boxes 14x14x14 inches inside measurement. The inner surfaces were coated with paraffin. The boxes of good-color muck contained 87 pounds, the others 80 pounds. The boxes were brought up to weight every third day or oftener by the addition of distilled water through a glass cylinder which reached to the bottom. The water content of the surface 5 inches was kept at 125 per cent of the dry weight of the muck except for three boxes which were kept at 190 per cent.

Analysis of the two mucks showed that the good-color muck had 55 per cent more total ash content than the other. The good-color muck had much more SiO_2 , K_2O , S, Fe_2O_3 , and Al_2O_3 , but less CaO , and MgO than the poor-color muck. There was slightly more P_2O_5 in the good-color muck. The soil reaction of the good-color muck was pH 5.45; of the other, pH 5.65. The fertilizers indicated in Table I were incorporated with the surface 4 inches of muck. Each treatment was set up in triplicate. Eighteen Ebenezer sets were planted in each box

November 7, 1929. The photoperiod was kept at 15 hours by the use of 100-Watt plain glass Mazda lamps suspended 3 feet above the muck.

TABLE I—THE EFFECT OF VARIOUS TREATMENTS ON THE THICKNESS OF SCALE OF ONIONS

Box No.	Treatment at acre rate	Thickness of First Inclusive Scale Midway up the Side of the Bulb (Millimeters)
Poor Onion Color Muck		
1	1000 lbs. of 2-8-10	0.0211±0.0011
2	1000 lbs. of 2-8-10	0.0224±0.0021
3	1000 lbs. of 2-8-10	0.0211±0.0011
4	1000 lbs. of 2-8-10 plus	0.0223±0.0018
5	50 lbs. CuSO ₄	0.0269±0.0003
6		0.0233±0.0010
7	1000 lbs. of 2-8-10 plus	0.0244±0.0017
8	50 lbs. MnSO ₄	0.0247±0.0005
9		0.0266±0.0007
10	1000 lbs. of 2-8-20	0.0224±0.0016
11	1000 lbs. of 2-8-20	0.0227±0.0005
12	1000 lbs. of 2-8-20	0.0224±0.0006
13	1000 lbs. of 2-8-25	0.0258±0.0005
14	1000 lbs. of 2-8-25	0.0239±0.0005
15	1000 lbs. of 2-8-25	0.0255±0.0007
16	1000 lbs. of 8-8-10	0.0229±0.0005
17	1000 lbs. of 8-8-10	0.0283±0.0017
18	1000 lbs. of 8-8-10	0.0220±0.0008
19	1000 lbs. of 2-8-10 with H ₂ O at	0.0241±0.0010
20	190% of dry weight	0.0241±0.0009
21		0.0235±0.0002
Good Onion Color Muck		
22	1000 lbs. of 2-8-10	0.0360±0.0005
23	1000 lbs. of 2-8-10	0.0351±0.0011
24	1000 lbs. of 2-8-10	0.0371±0.0003

The onions were harvested April 2, 1930. The thickness of the first complete dry scale was measured with a micrometer midway up the side of the bulb. The results are given in Table I.

None of the treatments had any effect on the color. While there are slight differences in thickness of scale, none of those on the poor-color muck approached the thickness of the scales of the good-color muck bulbs. These latter had a fair degree of pigmentation.

In this experiment the phosphorous applications were not varied. A test for phosphorous made by the "Hi-lo-phos" method at the end of the experiment showed a striking difference in favor of the good-color muck.

TABLE II.—THE EFFECT OF FERTILIZER TREATMENTS ON THE COLOR AND THICKNESS OF SCALE OF MUCK-GROWN ONIONS

Treatment at acre rate	Crop of October 31, 1930 to March 19, 1931		
	Average Thickness of Scale (Millimeters)	Average Thickness of Scale (Millimeters)	Approximate Color
<i>Good color muck</i>	A ¹	B ¹	
1000 lbs. of 3-12-18.....	0.0349±0.00087	0.0354±0.00117	Cream color
<i>Poor color muck</i>			
1000 lbs. of 3-12-18.....	0.0219±0.00041	0.0260±0.00032	Baryta yellow
1000 lbs. of 3-12-18 plus 150 lbs. of 16% superphosphate.....	0.0294±0.00029	0.0231±0.00058	Baryta yellow
1000 lbs. of 3-12-18 plus 225 lbs. of 16% superphosphate.....	0.0317±0.00068	0.0293±0.00050	Buff yellow
1000 lbs. of 3-12-18 plus 300 lbs. of 16% superphosphate.....	0.0334±0.00100	0.0370±0.00032	Ochraceous salmon
1000 lbs. of 3-12-18 plus 100 lbs. of CuSO ₄	0.0255±0.00026	0.0233±0.00047	Baryta yellow
Treatment	Crop of March 20, 1931 to July 16, 1931		
	Average Thickness of Scale (Millimeters)	Average Thickness of Scale (Millimeters)	Approximate Color
<i>Good color muck</i>	A ¹	B ¹	
1000 lbs. of 3-12-18.....	0.0444±0.00076	0.0489±0.00070	Salmon buff
<i>Poor color muck</i>			
1000 lbs. of 3-12-18.....	0.0349±0.00086	0.0339±0.00048	Naphthalene yellow
1000 lbs. of 3-12-18 plus 150 lbs. of 16% superphosphate.....	0.0398±0.00070	0.0393±0.00059	Naples yellow
1000 lbs. of 3-12-18 plus 225 lbs. of 16% superphosphate.....	0.0415±0.00076	0.0415±0.00108	Antimony yellow
1000 lbs. of 3-12-18 plus 450 lbs. of 16% superphosphate.....	0.0454±0.00070	0.0456±0.00097	Apricot buff
1000 lbs. of 3-12-18 plus 100 lbs. of CuSO ₄	0.0491±0.00097	0.0477±0.00070	Flesh ochre

Mean values were calculated for material grown in each container, separately.

More muck was obtained from the same general locations in October, 1930. The soil reaction of the good-color muck was pH 5.14; of the other, pH 5.36. Oil drums were cut in half, cleaned and coated with asphalt paint. Each container was equipped with an automatic watering system to maintain a constant water level. It required 180 pounds of good-color muck to fill one of the cans to the same level as did 170 pounds of poor-color muck of the same water content. The surface inch of muck in each drum was removed, the fertilizers indicated in Table II mixed with the next 4 inches of soil and the surface layer replaced. Each treatment was in duplicate (A and B). Thirty Ebenezer sets were planted in each can October 31. The photoperiod was the same as in the previous experiment. On November 11 the phosphorous test showed a gradient with those cans receiving the heaviest application of superphosphate to be about on the same level as the good-color muck. The crop was harvested March 19, 1931. The thickness of scale was measured as before and the approximate average color of the onions from each treatment was determined by comparison with Ridgway's standards. The data are given in Table II. Increased quantities of phosphorous have made thicker scales and have improved the quercetin content. There is no indication that copper sulphate has had any appreciable effect.

The top 8 inches of soil in each can was removed and mixed thoroughly. The same fertilizer applications were mixed with the muck as before, except in the case of cans 5 and 11 which received 450 pounds of 16 per cent superphosphate an acre in addition to the fertilizer, instead of 300 pounds. On March 20, 35 Ebenezer sets of the same lot as used before were planted in each can. On April 22 the same relative phosphorous contents were found, but all cans showed more than in the test made in the previous November. The crop was harvested July 16, 1931. The results are given in Table II. The duplicate cans have given very close average thickness of scale data in most cases. The phosphoric acid again has increased the thickness of the scale in proportion to the quantity supplied. Likewise the color has been improved. In this experiment the copper sulphate produced striking results, giving the best color and scale thickness of any of the treatments. It would appear that the 50-pound and 100-pound applications of the first and second experiments were inadequate to give the desired effect on this muck.

The effect of very heavy applications of muriate of potash and of superphosphate were tried on the muck at Elba in 1931. This muck had been cleared in 1929 and used for a crop of lettuce, followed by turnips in 1930, during which time it had received 50 pounds an acre of copper sulphate and two applications of 600 pounds each of 5-10-5 fertilizer. The basic fertilizer for 1931 was 1000 pounds of 16 per cent of superphosphate and 300 pounds of muriate of potash an acre. About 15 pounds of copper sulphate an acre were used in the oil-bordeaux spray. Extra superphosphate was applied to half a square rod at the rate of 4500 pounds to the acre. A similar sized plot received 1720

pounds of extra muriate of potash an acre. At harvest 50 consecutive bulbs were pulled near the center of each of the above plots and on an adjacent area receiving only the basic fertilizer. The color was best where the phosphoric acid was applied. The potash did not improve it over the basic fertilizer. The thickness of scale was as follows:

Basic fertilizer	0.0265 \pm 0.00080 mm.
Basic fertilizer + extra K_2O	0.0302 \pm 0.00140 mm.
Basic fertilizer + extra P_2O_5	0.0448 \pm 0.00195 mm.

A slightly better color was obtained by the use of 100 pounds of copper sulphate to the acre on a plot of muck in Orange County. The Smith-Canastota Company has been successful in getting onions to grow better, with also some improvement in scale color, on the muck at Chittenango by using 40 pounds of monohydrate copper sulphate to an acre. The onions are sometimes rotated with potatoes which are sprayed very heavily with Bordeaux thus adding more copper sulphate. Lyman Porter of Elba obtained a noticeable difference in the color of onions where for 2 years he had applied 33 pounds of 20 per cent monohydrate copper sulphate dust an acre, compared to the color of the onions on adjacent untreated plots. Another grower in the Elba muck area did not observe any improvement in pigment production following an application of 75 pounds an acre of copper sulphate crystals.

Those growers who make four or more applications of the oil-bordeaux spray for the control of onion maggots are adding at least 24 pounds of copper sulphate to the acre. This spray is applied directly to the small plants. Thus the concentration of the copper sulphate available to the roots is greater than if this quantity were broadcast over the area.

Felix (1) found that the quantities of copper sulphate needed to correct the rabbit-ear condition of lettuce on muck in the Elba area varied considerably on different plots of muck. The same is probably true in the case of onion scale color and explains why the results have varied in the cases mentioned.

No explanation is offered at this time of the mode of action of the constituents of the copper sulphate, or of the superphosphate in affecting the production of thicker scales and increased quantities of quercetin.

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Premature Seedstalk Formation in Table Beets

(Preliminary Report)

By EMIL CHROBOCZEK,¹ *Cornell University, Ithaca, N. Y.*

THE fact that exposure to relatively low temperature (40 to 50 degrees F.) in the early period of growth is the primary factor of premature seeding was clearly demonstrated by Thompson (1) with celery, and Boswell (2) and Miller (3) with cabbage. In a preliminary experiment in 1930, the writer obtained a similar indication for beets. In this experiment, plants started in the greenhouse and exposed to relatively low temperature for 30 days in the coldframe before transplanting to the field formed a considerable percentage of seedstalks.

In the fall of 1930, a greenhouse experiment was started in order to study under more adequately controlled conditions the question of premature seeding of beets. The object of this experiment was to study (1) the effect of age of the plants at the time of exposure to the cold temperature on seedstalk formation; (2) the influence of temperature on the plants after the cold treatment; and (3) the response of the cold-treated and of the check plants under long and short daylight conditions.

Plants for this experiment were started in a medium temperature greenhouse (60 to 70 degrees F.) on the following dates: Lot I, August 28; Lot II, September 7; Lot III, September 17; Lot IV, September 27; Lot V, October 7; Lot VI, October 17. Seed was sown in flats, the plants were transplanted into flats and spaced 2 inches x 2 inches, and later shifted into 6-inch pots.

On November 1, one-half of the plants of each age were transferred into the cold part of the greenhouse where the temperature was kept above 40 degrees F. and, if the outdoor temperature permitted, below 50 degrees F. The plants were exposed to these conditions until December 12. During this period the daily temperature on 30 days averaged from 40 to 50 degrees F., the rest of the time above 50 degrees F.

On December 12, the plants exposed to this cold temperature and the check plants of six different ages were placed in three different sections of the greenhouse, where the temperatures were as follows: in the cool house between 50 to 60 degrees F., in the medium-temperature house 60 to 70 degrees F., and in the warm house 70 to 80 degrees F. In each house, 20 plants of the treated and 20 of the check plants of each age were grown under the natural daylight conditions,

¹The writer wishes to express his appreciation to Dr. H. C. Thompson, under whose direction this work was conducted. He is also indebted to the Council of Polish National Fund of Education and Ministry of Agriculture for the granted fellowship which enable his studies in the United States.

and the same number of plants under long daylight conditions, using here 5 hours (from 5 to 10 p. m.) of additional electric light, furnished by 75-watt Mazda lamps suspended 29 inches above the greenhouse bench, and 29 inches apart. Seedstalk formation was recorded at 7-day intervals. The results obtained in the cool house are given in Table I.

TABLE I—COOL TEMPERATURE HOUSE (50 TO 60 DEGREES F.)

Lot No.	Number of Seed Stalks Formed Until							
	Jan. 26	Feb. 10	Feb. 21	March 7	March 21	April 11	May 2	May 24
Cold-treated Plants, Under Long Daylight Conditions								
I.	1	13	20	—	—	—	—	—
II.	—	9	17	20	—	—	—	—
III.	—	10	14	20	—	—	—	—
IV.	—	5	15	20	—	—	—	—
V.	—	2	12	18	20	—	—	—
VI.	—	5	13	20	—	—	—	—
Check Plants, Under Long Daylight Conditions								
I.	—	—	2	11	18	20	—	—
II.	—	—	1	11	17	20	—	—
III.	—	—	1	5	15	20	—	—
IV.	—	—	—	3	13	20	—	—
V.	—	—	—	2	8	20	—	—
VI.	—	—	—	1	7	20	—	—
Cold-treated Plants, Under Short Daylight Conditions								
I.	—	—	—	5	10	18	20	—
II.	—	—	—	7	12	17	20	—
III.	—	—	—	6	8	17	20	—
IV.	—	—	—	6	8	16	19	20
V.	—	—	—	3	7	15	19	20
VI.	—	—	—	2	3	19	16	20
Check Plants, Under Short Daylight Conditions								
I.	—	—	—	1	1	6	15	19
II.	—	—	—	—	—	7	17	20
III.	—	—	—	—	—	4	19	20
IV.	—	—	—	2	3	4	17	20
V.	—	—	—	—	—	1	12	20
VI.	—	—	—	—	—	—	13	20

In the cool house, all plants (480) except one went to seed; while in the warm house, where the light conditions were the same but the temperature ranged 20 degrees F. higher, not a single seedstalk developed.

The results from the medium temperature house are presented in Table II. The results obtained in this experiment brought out several interesting points. In the cool temperature house all plants went to seed, even those which were started and grown several weeks in the medium temperature house and which were not subjected to the cold

treatment. This indicates that even a temperature as high as 50 to 60 degrees F. is able to cause premature flowering in beets if the plants are exposed to it long enough. However, exposure to the relatively low temperature (40 to 50 degrees F.) hastened the formation of seedstalks. Further, these data check with the results obtained by Munerati (4), and Magruder (5) indicating that the beet is a long-

TABLE II—MEDIUM-TEMPERATURE HOUSE (60 TO 70 DEGREES F.)

Lot No.	Number of Seed Stalks Formed Until				
	Feb. 2	March 7	April 4	May 2	June 14
Cold-treated Plants, Under Long Daylight Conditions					
I.....	1	11	14	14	14
II.....	1	15	16	16	16
III.....	—	8	12	12	12
IV.....	—	7	12	12	12
V.....	—	2	8	8	8
VI.....	—	—	3	3	5
Check Plants, Under Long Daylight Conditions					
I.....	—	—	—	—	—
II.....	—	—	—	3	3
III.....	—	—	—	—	—
IV.....	—	—	—	—	2
V.....	—	—	—	1	1
VI.....	—	—	—	—	1
Cold-treated and Check Plants, Under Short Daylight Conditions No Seed Stalks Formed					

day plant. It does not flower during the short winter days under the normal daylight conditions; however, the use of 5 hours of a weak additional electric light shortened by 33 days the time required for seedstalk formation.

In the high temperature house not a single seedstalk was formed, regardless of the previous cold treatment of the plants and of the daylight duration. In these conditions the temperature 70 to 80 degrees F. was the factor preventing the plants from flowering, while in the cool house it was the shortness of the natural daylight in January and first part of February. The results of this experiment indicate that for flowering of the beet plant both proper temperature and sufficient daylight were necessary.

If, however, the seedstalks started to form in the cool house and if they were transferred into the high temperature, they elongated here much faster and reached the full blossoming stage about 4 weeks earlier than those left in the cool house. The plants growing in the cool house, however, produced taller and thicker seedstalks.

The results obtained in the medium temperature house indicate that 60 to 70 degrees F. was high enough to decrease markedly the

percentage of seeders of the cold treated plants grown under the long daylight conditions, especially of the younger plants, and nullify entirely the effect of the cold treatment of the plants grown under normal daylight. On the other hand, a few of the check plants produced seed stalks under the long daylight conditions. This experiment is to be repeated.

Results obtained under different light and temperature conditions indicate that these two factors of the environment may control the vegetative development and flowering of the beet. Another example of the influence of the environment on the direction of the development was obtained in the following experiment: In the fall, 1930, two plants bearing stalks which had not reached the flowering stage were transferred from the field into the greenhouse. One of them was placed in the cool house under long daylight conditions, the other was kept first for several weeks in the warm house and later in the medium temperature house under normal daylight conditions. The plant in the cool house produced new seedstalks from the top of the one formed in the field the year before, and was in full blossom at the end of March. The plant in the medium temperature house developed vegetatively, having formed on the top of the old stalk (12 inches high) an enlargement about $2\frac{1}{2}$ inches in diameter, resembling in shape the regular beet "root."

Another question, to which attention was given, was the influence of freezing on the seedstalk formation. Bartos (6) published in 1923 the results of a greenhouse experiment where he ascribed the formation of seedstalks in sugar beets, ranging in different lines from 19 to 100 per cent to the less than 1 hour exposure of the plants to the temperature of -2 degrees C. On the other hand, we have evidences from the experiments with celery (1) that freezing delays or even prevents seedstalk formation.

The writer had conducted an experiment with freezing of different lots of beets with the following results: (1) there was no influence of freezing on the plants grown before and after the frost treatment in the medium temperature; (2) plants, however, which were started in the medium temperature house and exposed for 2 months in the temperature ranging from 40 to 50 degrees F, and then frozen, formed seedstalks about 5 weeks earlier and in slightly higher percentage than the plants with the same cold treatment, but not subjected to freezing, and (3) plants grown before and after the frost treatment in the cool house were delayed in seedstalk formation if they were markedly injured by the freezing treatment.

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Self-Sterility and Fertility in Garden Beets as Indicated by Seed Production under Paper Bags

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IN a previous paper (1), based on a relatively small number of plants, it was shown that since some beet plants set a reasonable percentage of seed under glassine bags, the bags themselves had little if any deleterious effect on fertilization. The data also showed considerable variation in the percentage of flower clusters producing germinable seed but the presence of a number of plants that set seed on 5 per cent or more of the bagged flower clusters indicated the possibility of isolating lines that were highly self-fertile.

The present paper presents data covering a larger number of plants grown during 1930 from roots the seed for which came from two plants selected from the Detroit Dark Red variety and grown in close proximity in an isolated location. The mother roots were planted in the field during the latter part of May and the bags attached during the latter part of July.

The main inflorescence of the plants was tied to a strong string which in turn was supported by stakes placed at intervals in the row. The individual bags were also supported by this string but tied to it in such a way that they were free to move a limited extent in all directions. Cotton was wrapped around the stem of the enclosed portion of the inflorescence at the point of attachment of the bag to prevent the entrance of pollen-bearing insects. One or more branches of the inflorescence, depending upon the size of the bag, were enclosed in each bag, the tip of each inflorescence being first removed to limit the amount of growth in the bag.

Several different sizes of glassine bags were used but the number of each on the plants which produced seed, was so small that no consistent differences were noted in the results obtained. A few 12-pound brown manila bags were also used and appeared to be fairly satisfactory. The greater number of the bags were 2 inches wide when flat and varied in length from 5.5 to 12 inches. Previous work indicated that narrow bags resulted in a better set of seed, probably because of better pollination. Bags 5.75 inches wide and 8 inches long (commonly used in fruit tree pollination studies) and some 8 inches wide by 17.25 inches long were also used in smaller numbers. All were of medium weight glassine with moisture proof seams and flat ends.

In order to enhance the chance for pollination, the bags were vigorously shaken just before or after noon each day during the blooming period.

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The bags were allowed to remain on the plants until the entire contents were dry. Only the intact bags were gathered and stored until the count of blossom clusters was made. All blossom clusters containing one or more ovaries that had visibly enlarged were removed and each counted as a single "seed" although it may have contained as many as five true seeds. In some cases the enlargement of the ovary was slight and the presence of a viable embryo doubtful but these were included in the count in order to obtain all the viable embryos.

Germination tests were made in soil in the greenhouse during April 1931. All available "seed balls" of each plant up to a maximum of 25 were space planted and a record kept of the number of seedlings emerging from each "seed ball."

RESULTS

A tabulation of the results shows that a total of 142 plants had one or more bags intact at harvest. Of this number, 116 plants carrying an average of 2.48 bags each, with an average of 260 flower clusters per bag, produced no enlarged ovaries. The range in number of bags per plant was 1 to 11, and the range in number of flowers per plant under bags was from 70 to 3072 with an average of 668.

While one would hesitate to draw definite conclusions concerning the self-sterility of plants on which only one bag containing approximately 200 flower clusters was intact, the fact that other plants under similar conditions gave fair sets of seed, would support the belief that if not completely self-sterile they were highly so. If the 33 plants in this class (only one bag intact) are included with the others having more than one bag per plant which failed to set seed, a total is reached of 81.6 per cent which appeared self-sterile.

The remaining 18 per cent (26 plants) produced one or more flower clusters in which at least one of the ovaries had become sufficiently enlarged to indicate the possible presence of a viable embryo. As shown in Table I, 4 of the 26 produced only one such cluster and in 11 plants less than 1 per cent of the clusters on each plant were visibly enlarged. Subsequent germination tests showed that 5 of these 11 plants failed to produce any seedlings. Eight of the twenty-six plants which produced enlarged ovaries, or an additional 5.6 per cent of the total number, failed to produce any seedlings. Thus a total of 87.2 per cent of the plants involved in this test failed to perpetuate themselves. This is a higher percentage of sterility than was found in 1927 and 1928 (1).

Of considerably more interest to the plant breeder is the remaining 12.8 per cent of the plants that indicated at least partial self-fertility by their capacity to produce viable embryos under glassine bags. Of particular interest are plants numbers 49, 72, and 84 in which more than 27 per cent of the enclosed flower clusters set seed. Not only was the percentage set high but the percentage of germinable seedballs and number of seedlings per germinable seedball, and per seedball planted, was also high. In two of these plants, 72 and

84, all intact bags contained seed balls, and in the third plant, 49, four out of five bags contained seed balls. All of which indicates that these plants were highly self-fertile and capable of producing a sufficiently large progeny to satisfy the requirements of most plant breeders and geneticists.

TABLE I—THE PRODUCTION AND GERMINATION OF GARDEN BEET SEED UNDER PAPER BAGS

Plant No.	Number of Bags		Flower Clusters			Per cent Germinable Seedballs	Number Seedlings per	
	Intact	With Seed	Total No.	With Seed			Germinable Seedball	Seedball Planted
				Number	Per cent			
22	3	2	855	7	.82	28.5	1.00	.28
23	4	2	1212	3	.24	0.0	.0	.0
26	4	3	1856	10	.53	90.0	2.00	1.80
29	4	2	1795	90	5.01	62.0	1.76	1.66
30	3	2	824	33	4.00	31.2	1.30	.40
39	3	1	2180	10	.45	71.4	1.80	1.28
49	5	4	754	328	43.50	89.0	1.94	1.73
68	3	3	704	19	2.69	73.6	1.35	1.00
71	4	3	826	123	14.89	78.6	1.49	1.13
72	4	4	1076	291	27.04	94.0	1.73	1.63
73	4	2	1334	66	4.94	59.2	1.31	.77
83	1	1	310	15	4.83	93.3	1.78	1.66
84	4	4	668	226	33.83	91.7	1.96	1.80
95	2	1	182	5	2.74	0.0	.0	.0
99	4	1	554	13	2.34	15.3	1.00	.15
110	3	1	768	1	.13	0.0	.0	.0
117	1	1	172	8	4.65	0.0	.0	.0
124	2	1	282	18	6.38	22.2	1.00	.22
125	2	1	402	1	.24	0.0	.0	.0
128	3	1	672	2	.29	50.0	2.00	1.00
130	4	1	656	1	.15	0.0	.0	.0
133	7	2	2904	20	.68	10.0	1.00	.10
142	2	1	218	5	2.29	40.0	1.00	.40
155	2	1	206	2	.97	0.0	.0	.0
163	3	1	340	1	.29	100.0	1.00	1.00
179	2	2	346	6	1.73	0.0	.0	.0
116 Plants	298	0	77501	0	0	0	0	0

Attention should also be called to the fact that there was a tendency in the self-fertile plants to produce more than one viable embryo per seedball. Three seedlings per seedball was not uncommon and the high average of plants 49 and 84 was due to several four- and five-embryo "seed balls."

DISCUSSION

In view of the recently published work of Archimowitsch (2), some doubt is raised as to whether the seeds produced under the glassine bags in this experiment were actually pollinated with pollen from the same plant or with pollen from other neighboring plants. Archimowitsch found in 1927-28 that 16.7 per cent of the seedlings produced from seed grown under glassine were hybrids. In 1928-29 the percentage of hybrid seedlings was 37.6.

He explains the presence of these hybrids by assuming that they were the result of fertilization by pollen which had fallen on the spike before it was covered with the parchment bag. By dipping the spikes or branches of the inflorescence into tobacco extract in order to destroy plant lice and incidentally any pollen that might be present, he was able to reduce the percentage of hybrid seedlings in two later experiments to 6.7 and 5.4 per cent.

Discarding the idea of the possible oversight of faulty bags and assuming the complete elimination of ungerminated pollen, makes necessary the assumption that these hybrids were the result of pollination and subsequent fertilization which took place before the wetting of the spike. This raises the question of the relative age of the flower at which pollination can take place. According to Charetschko-Sawitzkaja (3) beet pollen will germinate on stigmas and fertilize flowers 6 days before they would normally dehisce.

It should be stated that in the present experiment the spikes were not wet before bagging and at least a portion of the bags were put on after an abundance of pollen was present in the air. It is entirely possible that a portion of the viable embryos produced under bags in this experiment were the result of cross pollination but the absence of any viable embryos on 87 per cent of the plants grown under the same conditions would seem to indicate that the conditions for cross pollination previous to bagging and immediately following were not as favorable as in the Russian experiments cited. Since these plants were all of the red fleshed type and had not been reduced in vigor by inbreeding it was not possible to detect hybrids in the resulting seedling plants.

Recognition and verification of this source of error will increase the apparent percentage of self-sterility in previous work of this type, decrease the percentage of true self-fertility and make more pertinent the isolation of truly self-fertile individuals for breeding and genetic work.

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The Successful Pollination Period of Garden Beets, *Beta vulgaris*

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AS a part of the general problem of plant breeding technique with the garden beet and in order to expedite the work of selfing or hybridization, it seemed desirable to determine the maximum length of time that beet flowers would remain receptive.

In attacking this problem, two methods of procedure were followed. On certain plants the central or terminal flowers were emasculated in all the clusters that would normally open (anthers dehisce) the next day; and the lateral or basal flowers were removed by pinching them off with fine pointed tweezers. The apical portions of the spikes were removed and the emasculated flowers were then covered with a glassine bag, cotton being wrapped around the stem of the plant at the point of attachment to prevent the entrance of pollen-carrying insects. A few flowers were pollinated each day, usually in the afternoon, with a mixture of pollen from several plants applied with small camel's hair brushes. Jewelers' small paper tags were attached to each flower.

In the second method the flowers that opened on the current day were either pollinated or removed and all the central flowers that would open during the following 4 to 7 days were emasculated and the basal flowers removed. As soon as the first unemasculated flower or flowers at the distal end of the spike opened, the bag was removed, all flowers were pollinated with pollen collected from several plants and the bags replaced.

In calculating the date on which the various flowers would have opened, it was assumed that flowering proceeded at a uniform rate. Thus, if over a period of 5 days, 15 flowers opened, it was assumed that 3 opened each day and this figure was used in determining the date of opening of each emasculated flower. This method of calculation is admittedly only an approximation as blooming studies showed that the number of flowers opening or dehiscing each day varied according to weather conditions, position on the plant and between plants within a variety.

It should also be pointed out, that emasculation and removal of the lateral or basal flowers from a cluster is a very tedious and difficult task to perform without irreparably injuring the flowers. No doubt the lower percentage of enlarged ovaries in the emasculated flowers was partly due to injuries sustained during emasculation. Table I shows that emasculation alone materially reduced the percent set when compared with flowers on the same spike that were not emasculated. The

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removal of the basal flowers was probably more severe than emasculation.

Because of the great amount of time required, it was possible to work on only a rather small number of plants and the data are therefore limited in extent.

TABLE I—THE EFFECT OF EMASCULATION OF BEET FLOWERS ON THE SET OF SEED

Plant No.	Emasculated		Not Emasculated	
	No. Flowers	Per cent Set	No. Flowers	Per cent Set
1	54	90.7	11	100.0
2	54	90.7	2	100.0
3	55	72.7	11	81.8
4	39	25.6	29	75.8
11	36	86.1	33	93.9

1927 RESULTS

The 1927 work was conducted in the greenhouses of the Department of Vegetable Crops of Cornell University. The Crosby Egyptian variety was used. The plants began blooming the last of April.

On plant No. 1, three flowers were pollinated the same day (in the afternoon) that the anthers dehisced and all three produced a normal size seed. Two of the three seeds germinated when planted 2 years later. Three flowers that were pollinated 1 day after they would have opened normally, produced two enlarged ovaries but neither germinated. Two days after opening one flower was pollinated but it did not "set" seed. Three days after opening six flowers were pollinated and none set seed. Three were pollinated 4 days after normal opening and none set seed. Four were pollinated 5 days after opening and none set seed. These results would indicate that pollination the same day that anthers dehisced was successful in accomplishing fertilization but that it could not be delayed longer than one day after opening.

On plant No. 2 a total of five flowers located on four different spikes were pollinated the same day that the anthers dehisced. All five set seed but only two germinated. A total of 42 blossoms that would have opened over a period of 7 days on the four spikes were also emasculated. Only two produced seed and these were not over one day from dehiscence and may possibly have dehisced (if not emasculated) the same day pollinated.

Plant No. 4 had a total of 16 flowers on 4 spikes that were pollinated the same day they opened and 14 of them set seed. One out of two that were pollinated one day after opening, set seed. Others were pollinated at daily intervals until 5 days after opening but none of these set. Emasculated flowers numbering 104 on 4 spikes that would have opened over a period of 8 days, when pollinated on the ninth day, produced only two seeds and these were of the eighth day's bloom (only one day old).

1928 RESULTS

The 1928 experiments were carried out in the gardens of the Ohio Agricultural Experiment Station during the last two weeks of July and the first week of August.

One plant of the Extra Early Egyptian variety on which 5 flowers were pollinated the same day they opened produced only two good seeds. None of the 31 emasculated flowers which developed during a period of 8 days produced any seed.

Another plant of the same variety produced no seed from four flowers pollinated the same day they opened, or from the 15 emasculated flowers which matured during a period of five days.

A Crosby Egyptian plant produced four seeds from four flowers that were pollinated on the same day they opened. Of the emasculated flowers which developed at the rate of three each day over a period of 7 days, two that were 1 day old, three (100 per cent) that were 2 days old, one that was 3 days old, and one that was 4 days old set seed.

Another Crosby Egyptian plant set seed on four out of six flowers that were pollinated the same day they opened. It also set seed on three out of four emasculated flowers that were pollinated 1 day after dehiscence, and the same proportion on the 2-day old flowers.

One Early Blood Turnip plant set seed on two out of four flowers that were pollinated the same day they opened. None of the emasculated flowers set seed.

An Early Eclipse plant produced seed in all of the four flowers that were pollinated the same day the anthers dehisced, but none of the 13 emasculated flowers that developed over a period of 4 days and were pollinated at the end of that time.

DISCUSSION AND SUMMARY

Emasculatation without the removal of the basal buds of each flower cluster reduced the percentage of flowers which produced seed. As pointed out above, the injury due to removal of the basal flowers may have been partially responsible for the low set of seed from the flower clusters so treated. Since the size of flowers varies somewhat from plant to plant and between varieties, it is conceivable that some plants or varieties are more susceptible to injury than others which might be advanced as one reason for the variable results obtained.

Although the number of flowers and plants involved is small, the evidence from the greenhouse grown plants would indicate that at least a part of the emasculated flowers pollinated in the afternoon of the day following dehiscence might be expected to produce germinable seed. The Ohio experiments would extend this period of receptivity to 2 and perhaps 3 days under garden or field conditions.

The fact that 81 per cent of the flowers that were pollinated during the afternoon of the same day in which their anthers dehisced, set seed, would seem to indicate that pollination 4 to 7 hours after de-

hiscence results in fertilization. This contradicts the belief expressed in many early books on the beet, that pollination did not take place until the following or second day after dehiscence but supports the work of Van Heel (2) and Artschwager (1) who have shown that the embryo sac is sufficiently mature at the time of dehiscence that pollination and fertilization may theoretically take place immediately. Archimowitsch (3) working with sugar beets, found that the greatest percentage of emasculated flowers produced seed when pollinated at the time of emasculation. Charetschko-Sawitzkaja (4) carried on experiments extending in both directions from the time of emasculation (probably the day before normal dehiscence) and found that buds emasculated and pollinated as long as 6 days before blooming would produce a small percentage of germinable seeds, and that pollination could be delayed from 8 to 9 days after blooming and still produce a small percentage of viable seeds. The greatest percentage of germinating seeds was produced by pollination on the third day following emasculation. Pollination at the time of emasculation resulted in an 81 per cent germination of the resultant seeds.

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Some Effects of Wounding Onion Bulbs on Seed Production

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SOON after it was found that certain Utah soils and the Utah climate were well adapted for the growing of Spanish onions, several growers undertook to produce seed of the Riverside Sweet Spanish variety. This was necessary to supplement the limited supplies of seed of this variety then available and to make certain needed improvements in the variety as it then existed. In some respects these first attempts did not prove successful. In order to improve the keeping quality and still retain the large size, the largest and hardest bulbs were selected for propagating stock. It was found that the best of these bulbs either failed to grow or did not grow until too late to produce a seed crop. Many of those which did grow produced only one or two unthrifty seed stems. Because of such conditions, these studies were undertaken by the author as part of the vegetable research program of the Utah Agricultural Experiment Station.

METHODS

The problem was attacked from two angles, namely, fall-planting of uncut bulbs and spring planting of wounded bulbs. As soon as mature bulbs could be obtained in the fall, they were set in furrows which had been previously irrigated, and covered to a depth of about 1 inch. The second method included the planting of wounded bulbs in early spring. Two types of wounds were made at first. A cut was made through the apex of the bulb in the longitudinal plane, about one-half the distance through the bulb. The second type consisted of two such cuts at right angles to each other. These are designated in the discussions as "cut once" and "cut twice," respectively. After the first year another type of wounding was included in the tests. This consisted of cutting away the top half of the bulb, according to the Spanish method, and planting only the lower half. All of these methods were compared with uncut bulbs of the same parentage. Records were made of the percentage of stand, number of seed stems, and yield of seed. All plats were given clean cultivation and provided with adequate irrigation. The soil was a fine gravelly sandy loam containing a large amount of organic matter.

During the last two months some preliminary chemical analyses have been made in order to find an explanation for the behavior of bulbs under the conditions of this experiment.

The strain used in these studies was one that had been carefully and consistently selected for shape, firmness and color for five generations. Each selection was a mass selection. All generations were represented in the field studies but only the progeny of the last genera-

tion was used in the chemical studies. For the chemical analyses 50-gram samples of both stems and bulb tissue were extracted with alcohol in the usual manner. The master sample included from 25 to 30 bulbs of approximately the same size and shape.

TABLE I—PERCENTAGE STAND, NUMBER OF SEED STALKS, AND YIELD OF SEED FROM WOUNDED AND UNCUT ONION BULBS

	1925	1926	1927	1928	1929	1930	1931
Bulbs Planted							
Cut 1.....	100	100	613	776	740	890	534
Cut 2.....	100	100	626	763	740	890	534
Topped.....	—	100	638	809	740	890	534
Uncut.....	678	100	597	780	740	890	534
Fall.....	225	328	—	—	—	—	—
Percentage Stand							
Cut 1.....	81	73	95	97	94	95	95
Cut 2.....	96	82	95	99	93	95	86
Topped.....	—	75	97	94	91	94	91
Uncut.....	83	63	93	84	93	93	90
Fall.....	50	18	—	—	—	—	—
Average Number Seed Stalks per Plant							
Cut 1.....	3.96	4.66	4.00	4.47	—	—	3.12
Cut 2.....	3.44	4.30	3.93	4.36	—	—	2.50
Topped.....	—	3.90	4.00	3.95	—	—	3.10
Uncut.....	3.67	3.66	5.08	4.15	—	—	2.30
Fall.....	4.57	4.80	—	—	—	—	—
Ounces of Seed per Plant							
Cut 1.....	.27	.405	.34	.55	.64	.12	.21
Cut 2.....	.33	.400	.345	.56	.56	.12	.13
Topped.....	—	.30	.32	.42	.33	.10	.13
Uncut.....	.18	.210	.41	.41	.47	.05	.13
Fall.....	.61	.44	—	—	—	—	—
Ounces Seed per Seed Stalk							
Cut 1.....	.070	.087	.086	.12	—	—	.065
Cut 2.....	.097	.092	.085	.13	—	—	.053
Topped.....	—	.076	.080	.098	—	—	.057
Uncut.....	.049	.060	.070	.100	—	—	.048
Fall.....	.132	.091	—	—	—	—	—

FIELD RESULTS

Seven years' results are now available. These data are briefly summarized in Table I. Considerable difficulty was experienced in wintering-over the plants from the fall-planted bulbs. In 1925, 50 per cent of the bulbs survived the winter, while in 1926 only 18 per cent of the bulbs were alive in the spring. The bulbs which survived the winter produced the most vigorous plants, the largest and most vigorous seed stems, and the most seed per plant. Because of the hazard attached to over-wintering the bulbs, this phase of the work was discontinued after 2 years.

In 5 out of 7 years all types of wounded bulbs produced larger yields of seed than the uncut bulbs. In 1927 the uncut bulbs were distinctly superior to all others from the standpoint of seed production. In 1931 the uncut bulbs equalled the "cut-twice" and "topped" bulbs, but were lower in seed production than the "cut-once" bulbs. Both of these exceptions are due to unfavorable weather conditions as related to the time of come-up of the plants, as will be shown later.

The superior seed-producing ability of the wounded bulbs over the uncut bulbs is associated with several responses. Among these may be mentioned: (1) Earlier come-up; (2) better mature stand, (3) larger number of seed stalks, (4) larger seed production per plant, and (5) larger seed production per seed stalk. Each of these will be discussed briefly.

An examination of the data of Table I will show that while there is not a great deal of variation in the percentage of bulbs producing mature plants, the uncut bulbs as a rule produced the poorest stand. However, the differences in seed production cannot be accounted for, to any great extent, by the variation in stand. The average number of seed stalks also shows some variation. With the exception of 1927, the "cut-once" series had the largest average number of seed stalks per plant. The "cut-twice" series was second, the "topped" series third, and the uncut in most cases was lowest in number of seed stalks per plant. Even these differences are not sufficient to account for the larger seed-yielding capacity of the wounded bulbs. Under favorable conditions for growth, the greater vigor both of leaves and of inflorescences of the plants from wounded bulbs is outstanding. Apparently, the wounding stimulates some physiological activity which results in this greater vigor. There is some indication that flower-bud differentiation is influenced by the wounding as reflected by the larger number of seed stems per plant.

There is a distinct difference in the date of come-up between the wounded and uncut bulbs. Boswell (1) presented data to show that transverse cuts in onion bulbs stimulated top growth and that wounded bulbs commenced to grow sooner than the unwounded ones. This observation is confirmed by the data of this study, as evidenced by the earlier "come-up" of the wounded bulbs.

Table II presents the data for 1927 in respect to dates of growth. The bulbs were planted in irrigated furrows on March 26. By April 19 a larger percentage of the topped bulbs were showing growth above ground than any of the other series and the uncut bulbs were showing the least amount of growth. The order of growth was in the same direction as the severity of wounding. By April 29, only 83 per cent of the uncut bulbs were growing, as compared to more than 95 per cent of the wounded bulbs. But in 1927 the uncut bulbs produced the largest quantity of seed. It will be noted in Table II that on July 7 there were fewer plants alive than on April 29, in all of the wounded series. The greatest mortality occurred in the most severely

wounded series (topped) and the least in the "cut-once" series. Some of the plants from the topped bulbs died nearly every year; the vigor of the remaining ones was below that of the "cut-once" and "cut-twice" series. It is probable that this is associated with a more rapid rate of decay. However, Boswell points out that cutting too close to

TABLE II—NUMBER OF BULBS GROWING AT DIFFERENT DATES IN 1927

Treatment	Bulbs Planted	Number Growing		
		April 19	April 20	July 7
Uncut.....	597	179	498	558
Cut once.....	613	395	587	572
Cut twice.....	626	485	598	557
Topped.....	638	528	619	582

the stem may cause injury. But in 1927 and in 1931 climatic factors also interfered with the growth response of the wounded bulbs. The 1927 season was marked by severe freezes during the first half of April. All of the plants above ground were frozen. Since the wounded bulbs produced earlier plants, these series suffered most. Although relatively few of them were killed outright, those remaining were so reduced in vigor that they never fully recovered from the injury. The delayed growth of the uncut bulbs made it possible for them to escape this damage. On April 22, 1931, a terrific 3-day wind cut away all top growth by drifting sand. As a result, the earliest growing series (the "cut-twice" and topped) were damaged, while the "cut-once" and uncut series escaped most of the injury because of their delayed growth. As a result of these set-backs, the uncut bulbs outyielded all others in 1927 and equalled the "cut-twice" and "topped" series in 1931. It is probable that after the first leaves are destroyed that the bulb is unable to produce a second equally vigorous growth. Rots will invade the wounded tissue more rapidly than the uncut and deplete the nutrient supply at an earlier date.

Even in the unusual years of 1927 and 1931, the seed yield per seed stalk was greatest in the "cut-once" and "cut-twice" series, as shown by the data of Table I under the division designated as ounces of seed per seed stalk. This also suggests that the higher yields from the cut bulbs is probably due to increased vigor as well as to better stand and a larger number of seed stems per plant.

RESULTS OF CHEMICAL ANALYSES

Some preliminary chemical analyses were made to determine if possible what changes in composition are associated with the behavior of wounded onion bulbs. One lot of bulbs was "cut twice" and kept in the laboratory for a period of ten days. A comparable lot was left uncut and kept under the same conditions as the wounded bulbs. Total and reducing sugar, soluble and insoluble nitrogen, and the

catalase activity were determined for both lots at 5- and 10-day intervals. Determinations were made for the stems and bulb scales separately. Some of these data are presented in Table III.

TABLE III—PERCENTAGE COMPOSITION OF WOUNDED AND UNCUT ONION BULBS AT DIFFERENT DATES (DRY WEIGHT BASIS)

Treatment	Per-centage Dry Weight	Percentage Sugar			Percentage Nitrogen			Catalase Activity C.C.O ₂ Evolved in 5 Minutes
		Total	Reducing	Non-reducing	Soluble	In-soluble	Total	
Stems								
Initial bulbs...	17.06	39.0	8.3	30.7	0.95	1.15	2.10	3.81
Uncut 5 days...	18.7	34.0	9.0	25.0	0.80	0.95	1.75	4.21
Uncut 10 days...	20.6	37.0	11.7	25.3	0.80	1.00	1.80	4.66
Cut 5 days...	20.8	32.8	5.9	26.9	0.75	0.90	1.65	3.83
Cut 10 days...	20.8	44.5	9.3	35.2	0.75	0.90	1.65	5.00
Bulb Scales								
Initial bulbs...	7.12	73.0	73.0	—	1.35	1.25	2.60	0.2930
Uncut 5 days...	8.76	60.0	60.0	—	1.05	—	—	0.3280
Uncut 10 days...	8.78	94.0	63.9	30.1	1.15	1.05	2.20	0.2700
Cut 5 days...	9.46	87.0	50.8	36.2	1.00	—	—	0.7000
Cut 10 days...	9.15	92.0	71.0	21.0	1.30	1.15	2.45	0.6700

Space will permit but a partial analysis of these data. They are not entirely consistent in every respect, although they do indicate certain changes in the chemical composition of the bulbs. Since the variability in chemical composition was not determined the differences obtained may be within the limits of experimental error, although the master samples were considered sufficiently large to overcome much of the variability. The difference in the composition of the initial bulbs and the ones remaining in the laboratory for 5 days uncut are no doubt due to the difference in temperature between the storage house and the laboratory; hence, the initial bulbs should not be compared with the cut bulbs after 5 and 10 days. The differences in dry weight are not great after the first 5 days. This is due to the method of sampling. No exposed tissue was included in the samples from which dry weights were determined. At the 5-day period there was a slight reduction in percentage of total sugars in the stem and an increase in the bulb scales, on dry-weight basis. At the 10-day period there was an increase in total sugars in the stems and a slight decrease in the bulb scales. In the stems the percentage of reducing sugar

was lower in the cut than in the uncut stems at both the 5- and 10-day periods. In the bulb scales the percentage of reducing sugar was lower in the cut bulbs at 5 days than in the whole bulbs, but at 10 days it was higher. It is probable that parts of this inconsistency is due to the proportion of outer bulb scales included in the sample. If only the inner bulb scales had been included different results might have been obtained.

The percentage of both soluble and insoluble nitrogen was lower in the cut stems than in the uncut. The cut stems at five and ten days showed the same composition in this respect. Apparently, some of the changes in sugar content are associated with this decrease in total nitrogen. The data do not indicate any marked changes in the nitrogen content of the bulb scales due to wounding.

The data on catalase activity, while inconclusive, do suggest that growth activities are greater in the cut bulbs than in the uncut ones. Boswell has already pointed out the probability that the differences in the response of onion bulbs to wounding is associated with the different rates of gaseous exchange in the cut and uncut bulbs.

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A New Method of Growing Cabbage Seed

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IN most sections where cabbage breeding and seed growing is practiced the plant is handled as a biennial. An exception to this is where the plants are given a rest period for 2 months at 40 degrees F. (1) and are then placed in a greenhouse for seed production.

In connection with a cabbage breeding project the author was interested in obtaining a considerable amount of seed from each of a number of selections. Certain strains are leafy and do not form heads and for this reason do not lend themselves to the cold storage treatment. Another disadvantage of the cold storage method for use in the South is that if spring-grown cabbage is placed in storage, it will have to remain there too long before it can be brought out and placed under conditions favorable for seed production. Fall-grown plants can be placed in cold storage for their rest period and brought out for seed production in the spring. The only disadvantage to this method is that, as a rule, there is a limited amount of storage space which can be used for such work.

For the past 2 years the cabbage plant from which seed was desired was grown in the open and treated as an annual. The seed are sown during the latter part of July and through August. The plants are set to the field the last of August and through September. During November and December the desired plants are selected and the heads cut and examined for such characters as core height and size, compactness, color, and flavor. If the head is satisfactory, the stump together with the roots is transplanted to a seed plot where the rows are 4 feet wide. The plants are placed 3 feet apart in the row. Soon after this all the sprouts growing out from the stump, except four or five, are removed while small. During December and January the sprouts develop into compact rosettes which are leafy and will resist freeze injury better than solid heads. These rosettes have been known to withstand temperatures as low as 18 degrees F. The mean temperature at Baton Rouge, La., for December, January and February (52.3 degrees F.) is such that seed-stalk development is initiated. During February these rosettes develop into small heads about 3 inches in diameter and remain in this condition until about the middle of March, when the seed stalks emerge. Seed from such plantings mature and can be harvested during late May and early June.

The advantages of this method over those practiced in other sections are that it affords a complete examination of each individual head character, and that with breeding work it is desirable to produce a large number of seed and to get at least one generation each year.

In addition to being able to grow this crop in the open where conditions are more nearly ideal, it is also less expensive than growing the seed in the greenhouse. Where the type has been fixed and where seed alone is desired, the mature heads may be sold for enough to cover the cost of practically all operations in growing the seed.

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Effects of Ringing on Growth and Fruiting in the Tomato¹

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THE practice of ringing, as a means of inducing fruitfulness in certain horticultural crops, has been confined largely to woody plants, and only a limited number of ringing investigations on herbaceous plants have been reported: Daniel (1) worked with the tomato and eggplant; Hedrick (2) with the chrysanthemum; Hedrick, Taylor, and Wellington (3) with the tomato and chrysanthemum; Broili (4) with the potato; and Kraus and Kraybill (5) with the tomato. In general these workers showed that ringing did not result in earlier flowering and ripening, larger size and yields of fruit, and better quality of product, although in a few cases some favorable results were reported.

The present investigation was undertaken to determine in more detail the effects of ringing tomato plants, on earliness of ripening, yields of ripe fruit, size of fruits, set of fruit, and on plant development and structure. The ringing was done by (A) removing a narrow band of cortex, and (B) constricting with a thin wire twisted tightly around the plant stem. These treatments were applied at various stages of plant growth.

MATERIAL AND METHODS

Plants of the Bonny Best variety of tomato, started in the greenhouse early in March, were planted in the field at University Farm, St. Paul, on May 20, 1929, and June 10, 1930. Plants were set 3 feet apart in rows 4 feet apart. All plants in the experiment were trained to single stems, trellised, and topped off above the sixth truss in order to facilitate the taking of records and at the same time to gain the favorable advantages known to result from these practices.

In the 1929 season, 10 treatments were used, namely:

- I. Plants not ringed—control.
- II. Constricted with wire before any flowers had opened.
- III. Constricted with wire after first flower opened on first truss.
- IV. Constricted with wire after first flower opened on third truss.
- V. Constricted with wire after first flower opened on fourth truss.
- VI. Constricted with wire 1 week after V.
- VII. Constricted with wire 2 weeks after V.
- VIII. Constricted with wire 3 weeks after V.

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- IX. One-half inch ring of cortex removed after first flower opened on third truss.
- X. One-half inch ring of cortex removed after first flower opened on fourth truss.

Constrictions and rings were applied to the stems in the region between the soil surface and the first node above the surface. Analyses of results obtained in 1929 showed that only results from treatments II, III, and X were significantly different from those of the control treatments, therefore, in 1930 only these three treatments were repeated.

In both seasons fruits were picked every second or third day, as soon as the fruit had assumed a red color over the entire surface. Picking dates and weights of individual fruits were recorded at each picking.

For purposes of analyzing the data, the fruit ripening season was divided into 10-day periods. Numbers of plants on which data were analyzed for the treatments showing significant differences were as follows:

Treatment	1929	1930
I. Control	25	53
II. Constricted with wire before any flowers open..	4	30
III. Constricted with wire after first flower open on first truss	49	26
X. Ring of cortex removed after first flower open on fourth truss.....	18	53

RESULTS

Changes in the structure and development of plants: Removing a half-inch ring of "bark" as in treatment X, caused but very slight, if any, reduction in size of plants as compared with control plants. Constricting with a thin wire when flowering had begun on the first truss (treatment III) produced a noticeable, but not excessive reduction in size. With treatment II, however, where a wire constriction was applied before flowering had begun, extreme reduction in plant size occurred. Frequently plants so treated attained heights of less than 3 feet in the entire season as compared with control plants with heights of 4 to 5 feet attained early in the fruiting season.

Use of wire constrictions early in the season (as in treatments II and III) resulted in an excessively high plant mortality due to winds breaking off the treated plants at the points of constriction. In the present experiment over 50 per cent of the original number of plants in treatments II and III were lost through such breakage.

Both removal of bark, and use of a wire girdle caused enlargement of the stems immediately above the points of application. Such enlargements were considerably more pronounced with wire constrictions than with bark removal. The ability of constricted stems to

"bridge" the wire girdles appeared to be closely related to the time of application of the wires. Only a small percentage of plants constricted before any flowers opened, bridged the wire by the end of the season. Among plants constricted after flowering had begun on the

TABLE I—AVERAGE NUMBER OF TOMATO FRUITS SET PER PLANT DURING THE 1929 AND 1930 RIPENING SEASONS

Treatment	Number of Fruits Set per Plant	
	1929	1930
I. Control.....	29.7	20.7
II. Constricted with wire before any flowers open.....	22.0	11.6
III. Constricted with wire after first flower open on first truss	25.7	19.2
X. Ring of cortex removed after first flower open on fourth truss.....	25.7	22.3

first truss, a much higher per cent of the plants formed complete calluses over the wires; nearly all plants constricted after flowering commenced on the third truss readily completed such calluses. Complete bridging-over of wounds likewise occurred in at least 90 per cent of the plants ringed by the method of bark removal.

TABLE II—YIELDS OF FRUIT PER PLANT DURING THE EARLY PERIODS OF THE FRUIT RIPENING SEASON

Treatment	1929		1930	
	Mean Yield (Grams)	Mean No. Frs.	Mean Yield (Grams)	Mean No. Frs.
	First 15 Days		First 12 days	
I. Control.....	253±26	2.1±.1	291±23	2.6±.2
II. Constricted before any flowers open...	0	0	232±25	2.8±.3
III. Constricted after first flower open on first truss.....	51	.4	162±19	1.7±.2
X. Ring of cortex removed after first flower open on fourth truss	280±34	2.4±.2	247±20	2.6±.2
	First 26 days		First 22 days	
I. Control.....	818±39	6.8±.3	569±33	5.1±.3
II. Constricted before any flowers open...	0	0	422±32	4.7±.4
III. Constricted after first flower open on first truss.....	342±28	2.6±.2	366±30	3.3±.3
X. Ring of cortex removed after first flower open on fourth truss	723±41	6.4±.4	406±23	4.2±.2

Two or three stems of plants from each of treatments I, II, III, and X, were sectioned with a sliding microtome, above, below, and in the immediate regions of the rings and constrictions. The sections were stained with safranin and light green as a means of differ-

entiating the structural regions, and were then examined under a microscope. Special attention was paid to the relative amounts of inner phloem. It was found that the amount of newly formed inner phloem was increased but very slightly, if at all, as a result of ring-

TABLE III—AVERAGE WEIGHTS OF RIPE TOMATO FRUITS FOR THE 1929 AND 1930 RIPENING SEASONS

Treatment	Average Weights of Fruits (Grams)	
	1929	1930
I. Control.....	128.2	112.1
II. Constricted with wire before any flowers open....	144.8	89.2
III. Constricted with wire after first flower open on first truss.....	126.7	121.8
X. Ring of cortex removed after first flower open on fourth truss.....	117.2	104.7

ing. This is in contrast to the work of Kraus and Kraybill (5) who "found that the internal phloem within the girdled area had greatly increased in amount."

Effects of treatments on set of fruit: In 1929 the set of fruit was reduced with treatments II, III, and X and in 1930 the first two of the three treatments showed reductions while the third gave a slightly increased fruit set as compared with the control treatment. Table I shows the mean number of fruits set per plant for the two seasons.

TABLE IV—TOTAL YIELDS OF RIPE FRUIT PER PLANT

Treatment	1929		1930	
	Mean Yield (Grams)	Mean No. Frs.	Mean Yield (Grams)	Mean No. Frs.
I. Control.....	2835±101	22.1±.8	1667±61	14.9±.5
II. Constricted before any flowers open.....	1267±127	8.8±.9	797±39	8.9±.4
III. Constricted after first flower open on first truss.....	1816±112	14.3±.9	1485±79	12.2±.6
X. Ring of cortex removed after first flower open on fourth truss.....	2143 ± 91	18.3±.8	1421±52	13.6±.5

Effects of treatments on earliness of fruiting: In Table II the yields of ripe fruits per plant are given for the initial ripening periods of both 1929 and 1930.

Examination of these data indicates that in no case was there a significant hastening of ripening due to the treatments used; on the contrary, in most cases treated plants show delayed rather than earlier ripening. Similar results were found to hold throughout the remainder of the season.

Effects of treatments on size of fruits: Average weights of ripe fruits for the two seasons are given in Table III.

Determinations of average weights of ripe fruits for individual 10-day periods throughout the ripening season, the data upon which are too voluminous to be presented here, indicated that the average size of fruits was somewhat increased in some of the later 10-day periods with treatments II and III. It is important, however, to notice that such increased size did not occur during the early part of the season when such increases are most to be desired.

Effects of treatments on total yield of ripe fruit: In all cases the total yield of ripe fruit per plant was reduced by ringing or constricting the plant stems, and the reduction in yield was apparently correlated with time of ringing or constricting. The extent of the yield reductions can be noted from the figures presented in Table IV.

DISCUSSION

The general conclusion of previous workers that ringing is a process of doubtful value with herbaceous plants is clearly corroborated by results obtained in the present experiments. The slight gains obtained in some respects appear to be more than offset by harmful effects in others, and in some cases there seem to be no benefits whatsoever gained by the plant from application of the practice.

One general theory of translocation, as commonly accepted, assumes that absorbed nutrients pass from the roots of the plant to the leaves chiefly through the more or less woody xylem, while the assimilated food is translocated through the phloem of the inner bark. When plants are ringed, the upward movement continues, but that downward is checked and the top of the plant is thus supplied with an extra amount of food at the expense of the parts below the ring.

Ringing has been successfully used on several species of woody, fruiting plants. Why is it then, that the practice generally fails to produce desired results when applied to herbaceous plants? The answer to this question probably lies more in the fundamental difference in growth habit of the herbaceous plant than in any great difference in the nature of the response of the plant to ringing.

Nearly, if not all plants on which ringing has been successfully used, are perennial in habit, and supplied with more or less extensive root systems; all the herbaceous plants on which the practice has been tried are annuals with more or less restricted root systems which are developed during the *same* season as that in which the ringing is done. Use of ringing is never advocated on woody plants until they have become well established—never before the second season and usually later than this, depending, of course, upon the plant. This assures the establishment of at least a reasonably good root system with capacity for storing organic reserves. When such a woody plant is ringed the root system can continue functioning practically normally even though assimilates from above are cut off by the ring, since it has reserves which will last for a time. Such is not the case, however, with the root system of the herbaceous annual; it has had no such opportunity to accumulate storage products, nor is it fully

extended at the time of ringing. As a consequence, it is not only unable to extend itself, but by its limitation in size is unable to supply the top of the plant with nutrients sufficient for normal growth.

Results of the present experiments indicate that the harmful effects of constricting tomato plants with fine wire, result only when the constrictions are applied early in the season, up to the time flowering begins on the third flower truss. In ringing after this early period, the plants quickly form calluses over the narrow wires, and go on functioning much as if no constriction were present. In the present investigations no cortex rings were removed prior to the time flowering began on the third flower truss. Ringing immediately after this date, however, gave results not significantly different from those of the control treatment, due no doubt to the root system being fairly well formed, and to fairly rapid bridging over of the ring. It is not entirely clear why removing a ring of cortex after flowering begins on the fourth flower truss produces harmful results, but it is suggested that the somewhat more mature tissues are slower in forming calluses over the wounds, thus inducing a temporary period of unbalanced nutrition in the plant. It should be noted, however, that the harmful effects are less severe in the latter case, than those resulting from early constriction with the thin wire girdles.

The close relationship existing between nutritional conditions, particularly carbohydrate and nitrogen nutrition, and fruiting in plants has been pointed out by numerous investigators. The general statement may be made that fruiting is associated with a condition of balance between the carbohydrate and nitrogenous constituents of the plant, and that ratios either excessively high or excessively low tend to produce an unfruitful condition. Limitation of the moisture supply has also been shown to cause unfruitfulness in the same way as a limited nitrogen supply.

The ringed herbaceous plant is limited both as to its moisture, and to its nitrogen supply, as a result of the limitation of root area. This limitation will tend, in the first place, to limit vegetative extension, which in turn will mean reduced synthesis and delayed fruit ripening. The setting of even a small amount of fruit will tend to further reduce the nitrogen available for vegetative extension since fruits require large amounts of nitrogen and will tend to utilize it even at the expense of the rest of the plant. The carbohydrate-nitrogen ratio is further upset due to action of the rings or constrictions in preventing downward movement of carbohydrates to the roots. We thus have developed a nutritional condition which Kraus and Kraybill (5) have shown to be unfavorable to fruiting. Results of the present experiment show that in all but one case ringing reduced the set of fruit. As would be expected, reduced total sets of fruit will result in reduced total numbers of fruits ripening, and likewise in reduced total yields.

It is recognized that the above considerations may not entirely account for the failure of ringing as a practice when used on her-

baceous plants. However, no one has published an explanation which would more satisfactorily account for this failure.

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A Study of the Regions of the Tomato Fruit as Affected by Selection

By E. C. STAIR and J. H. MACGILLIVRAY, *Purdue University, Lafayette, Ind.*

TOMATO varieties differ in the relative amounts of the separable regions (outer and inner wall, locular pulp, seed, and skin). The relative amount of wall material influences the appearance and thickness in tomato products and is an important quality characteristic from the canners' standpoint. Thick walls tend to preserve the wholeness of the fruit from the time it is picked in the field until the can is opened. Percentage of solids indicated by refractive index affects the yield of manufactured tomato products as they are usually sold on a water free basis.

Although it was realized that the relative amounts of the regions could be changed by hybridization it was considered wise to obtain some data relative to the effect of selection on these regions because if this method was effective it would be a more rapid means of improvement.

The tomato fruits used for this study were grown in the field on a fairly fertile soil. The seeds from one individual fruit selected previously were planted in the same row. The fruits were allowed to become red ripe before being harvested and no fruits were used that weighed less than 100 grams. The fruits used for study were selected from various plants in the row and were selected over the highest part of the production period.

The fruits were brought into the laboratory and each weighed separately. The regions were then separated for study by using the method described by McGillivray and Ford (7). After separating and weighing the various regions the juice of the entire tomato was extracted by means of a potato ricer. The juice was filtered from the pulp. The refractive index of the juice from each fruit was then determined by means of an immersion refractometer. The refractometer has been found by Bigelow and Stevenson (4) to be a very satisfactory means for determining the specific gravity of pulp, and although it may not be as accurate for single fruits as for pulp it was found to provide a very rapid means for comparison of the individual fruits. The drying method would undoubtedly be more accurate than the refractive index but the time required prohibited the use of this method.

The results found in Table I show in the first column averages of groups analyzed for the proportion of wall regions in 1928 and in the second column the selection made to be planted in 1929. Next is shown the averages of the regions for the seed planted in 1929 from which an individual fruit was selected for planting in 1930. A similar method was followed in succeeding years with refractive index and waste.

In the case of John Baer, two selections were made for a high percentage of wall and one for low. The averages resulting from these selections indicate that the fruits regardless of selection move towards the mean of all the fruits and there seems to be no progressive improvement. The selections made with the Indiana Baltimore gave similar results. No. 11 shows this same point can be illustrated by alternating the selection for a high and low percentage of wall.

TABLE I—WALL REGIONS AS AFFECTED BY SELECTION

Variety	Ave. Wall 1928	Selection 1928 Planted 1929	Ave. 1929	Selected 1929 Planted 1930	Ave. 1930	Selected 1930 Planted 1931	Ave. 1931
1. John Baer.....	72.5	65.7	69.8	63.1	71.1	—	—
3. John Baer.....	72.5	76.2	69.8	84.7	71.5	79.2	68.5
4. John Baer.....	72.5	75.5	70.0	80.4	73.3	—	—
9. Indiana Baltimore...	72.4	75.5	70.3	78.4	67.6	—	—
11. Indiana Baltimore...	72.4	80.8	65.6	62.0	68.0	85.0	61.9
13. Indiana Baltimore...	72.4	67.8	68.5	66.6	64.0	56.8	64.2
14. Indiana Baltimore...	72.4	65.1	74.0	80.4	70.6	75.0	69.1
15. Indiana Baltimore...	72.4	62.9	71.5	59.1	66.5	—	—
18. Baltimore x Balti- more.....	70.7	69.9	69.9	68.4	66.8	67.2	69.8
21. Baltimore x Balti- more.....	70.7	78.2	71.7	78.0	66.6	—	—
28. Baltimore x Balti- more.....	74.3	78.3	72.0	77.0	69.2	65.6	65.5
29. Baltimore x Balti- more.....	74.3	71.9	71.9	78.2	67.3	—	—

From the individual fruits obtained from No. 14 in 1930, two selections were made. One is given in Table I and the other, which had 68.3 per cent wall gave an average of 64.3 per cent in 1931 as compared to 69.1 for the higher wall selection. This might indicate a slight improvement from selection.

In Table II the refractive index was obtained by use of an immersion refractometer. All readings taken at or corrected to 17.5 degrees C.

In Table II in the case of John Baer No. 1, the selections in 1928 and 1929 were both made for a lower refractive index and in 1930 the selection was made for a relatively high index. Here as in the case of selecting for wall, the average returned in the direction of the mean. In the case of Indiana Baltimore the same results were obtained but it is of interest to point out in No. 14 where the selections each year were made higher than the preceding, that it seems as though some progressive improvement was made over the 4-year period, yet during the last year a second selection having a refractive index of 34.1 was planted and the average from this selection was 39.1 or about as the selection made for high refractive index.

In the Baltimore hybrids as shown in Nos. 18 and 21 where one was selected continually for high and the other continually for low,

the averages again returned in the direction of the mean for the group.

In 1928, 595 fruits were separated into their various regions and the refractive index of each fruit taken. Two hundred and fifty-three determinations were made in 1929, 378 in 1930, and 147 in 1931.

TABLE II—THE REFRACTIVE INDEX OF THE TOMATO JUICE AS AFFECTED BY SELECTION

Variety	Ave. R. I. 1928	Selected 1928 Planted 1929	Ave. 1929	Selected 1929 Planted 1930	Ave. 1930	Selected 1930 Planted 1931	Ave. 1931
1. John Baer	36.2	34.3	35.1	34.5	36.9	39.0	36.6
3. John Baer	36.2	38.7	35.8	35.3	35.6	34.4	37.7
5. John Baer	36.2	37.9	35.2	31.4	35.9	—	—
6. Indiana Baltimore . . .	35.4	38.8	35.8	35.6	36.6	—	—
9. Indiana Baltimore . . .	35.4	41.7	36.0	35.6	36.0	—	—
13. Indiana Baltimore . . .	35.4	33.8	35.6	39.0	35.6	35.4	36.7
14. Indiana Baltimore . . .	35.4	30.6	34.73	35.9	36.3	38.3	39.2
18. Baltimore x Baltimore	37.9	34.0	36.31	34.6	38.0	—	—
21. Baltimore x Baltimore	37.9	41.7	38.0	41.8	37.8	—	—
28. Baltimore x Unique . . .	34.6	38.3	35.7	36.1	37.6	37.4	38.7
30. Baltimore x Unique . . .	34.6	30.2	35.9	33.0	36.2	39.4	34.3

A biometrical study of the results secured in 1930 showed that there is no positive or negative correlation between a larger percentage of wall tissue and a higher concentration of the fruit juice.

The data secured while making this study with 1373 individual tomato fruits seems to indicate very definitely that raising or lowering the percentage of wall tissue, changing the concentration of the fruit juice, or altering the percentage of waste can be affected only very slightly, if at all, by selection (1, 3, 4).

It seems possible that the lack of progress in selection may be due to the working within a pure line in the John Baer and Indiana Baltimore varieties. However, as environmental conditions may affect the amounts of these regions it is also possible that environment is causing too much variation to effect improvement by selection.

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Tomato Color as Affected by Processing Temperatures

By JOHN H. MACGILLIVRAY, *Purdue University, Lafayette, Ind.*

IN canning factory practices of sterilization and concentration, tomato products suffer a serious impairment (1) in the redness and brightness of the color. It is generally believed that the color pigment is easily oxidized and color changes are noticeably affected by this reaction. During the past season, experiments were performed in an attempt to obtain further information relative to color changes by subjecting tomatoes to treatments and measuring the resulting color.

Color was measured by means of red, yellow, gray, and black discs intermingled in such a manner as to permit the exposure of different areas and rotated to produce a uniform color. Certain auxiliary equipment was used to increase the accuracy of these determinations and the color was expressed in terms of color rating previously described (1).

Tomatoes of as good color as obtainable were used, but the season of 1931 when these studies were made did not seem to have the correct conditions for producing tomatoes of a bright (chroma) color while the redness (hue) was almost normal with previous seasons.

There are several ways of removing oxygen from the cans, but unfortunately in all cases there are objections from the standpoint of color determinations and also it is customary to close a can with some headspace of air in the top of the can. It is believed that this work was performed under conditions such that the raw material had less oxygen than is usual under the best canning factory conditions.

TEMPERATURE EFFECTS ON CANNED TOMATOES

Tomatoes were peeled and quartered, and each quarter placed in a different No. 2 can (584 cc.) and one teaspoon of salt was added to each can. The cans were closed on a small hand machine which does not produce as good seams as an automatic machine. One can was used immediately for color determinations after pulping and the other four were placed in controlled temperature water bath regulated at different times for the temperatures shown in Fig. 1. The cans were processed 1 hour with a temperature variation of about ± 5 degrees C. The samples at 100 degrees C. in all cases were treated in boiling water. At the present time it is almost a universal practice to sterilize tomatoes by placing them in boiling water for about 30 minutes for No. 2 cans. It was not possible to obtain color analyses in as close agreement for canned tomatoes as for tomato juice.

The graph in Fig. 1 represents the average results of six samples at each temperature. It is evident that there is a smaller color impair-

ment at the lower temperatures and it is proportionally greater at the higher temperatures. These results are very similar to those found on tomato juice.

These experiments were not planned for determining processing temperatures nor were they in sufficient volume to justify any recom-

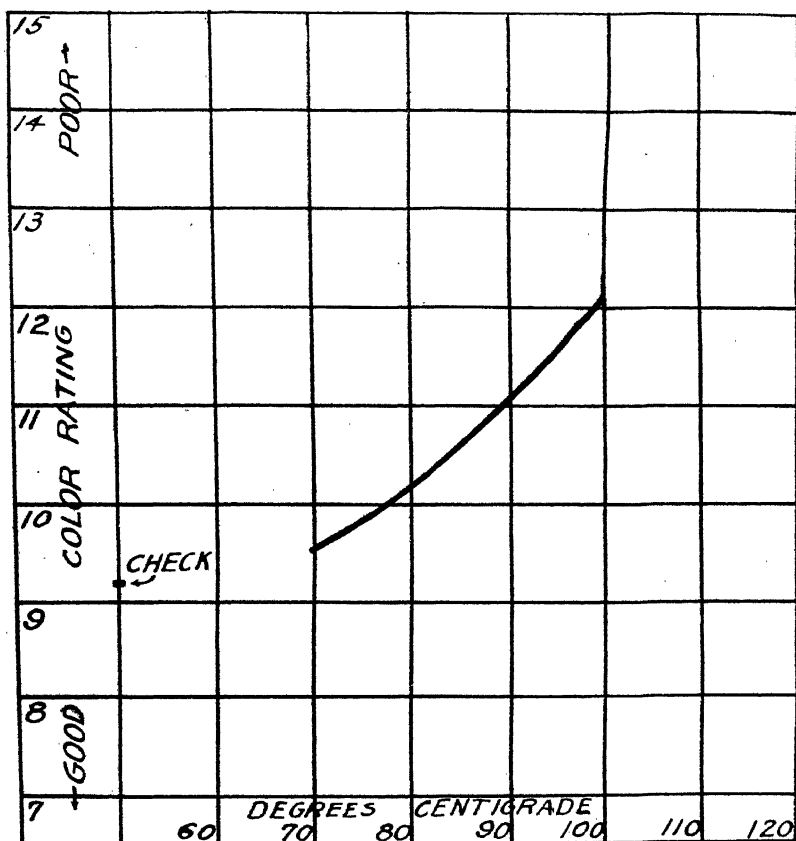


FIG. 1. Color changes in canned tomatoes as the result of processing in water for 1 hour at 70, 80, 90, and 100 degrees Centigrade.

mendations for a change in processing temperature. It was desirable, however, to determine roughly the probable sterilizing value of the temperatures mentioned above. Between September 11 to September 26, 12 No. 2 cans were processed at each of the following temperatures, namely, 70, 80, 90, and 100 degrees C. Only one can showed spoilage, and it had been processed at 80 degrees C. One-half of the cans, which did not show any indication of spoiling when kept in an attic for 2 weeks, were placed in an oven and incubated at a temperature of 98 to 100 degrees F. for 10 days without any spoilage.

TEMPERATURE EFFECTS ON TOMATO JUICE

A similar set of experiments was performed with tomato juice obtained by pulping tomatoes through a screen with holes .045 inch in diameter which removed skin and seeds. The juice was placed in No. 55 cans (246.6 cc.) and processed for 1 hour at the tempera-

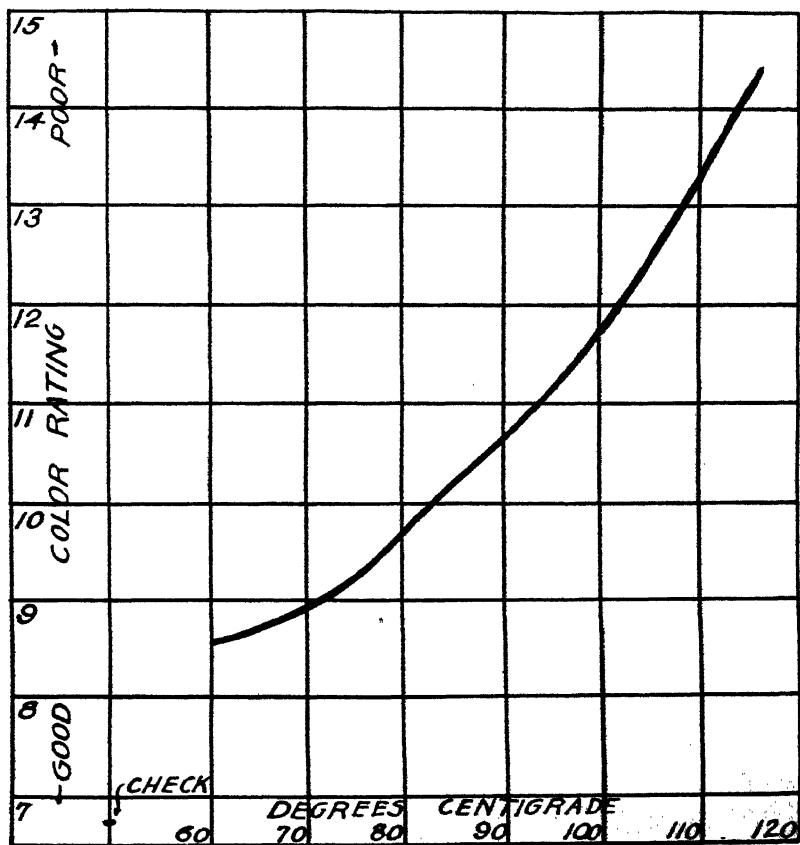


FIG. 2. Color changes in tomato juice as the result of processing in water for 1 hour at 60, 70, 80, 90, 100, and 116 degrees Centigrade.

tures shown in Fig. 2. The temperature of 116 degrees C. was obtained in a pressure cooker and recorded by maximum thermometers on the inside of the cans. All treatments were continued for a period of 1 hour.

The curve shown in Fig. 2 represents the average of seven experiments and gives evidence that as the temperature is increased the color is more seriously impaired. The curve becomes noticeably steeper as the temperature is increased. It is difficult to express accurately the

average of the seven results obtained at each temperature because the initial color was not the same for all test lots. In five of the series the initial color varied from a color rating of 6.48 to 7.01, and the greatest variability was at 80 degrees C. where the maximum and minimum varied by 1.45; while the average for the extremes of the six temperatures was but 0.85.

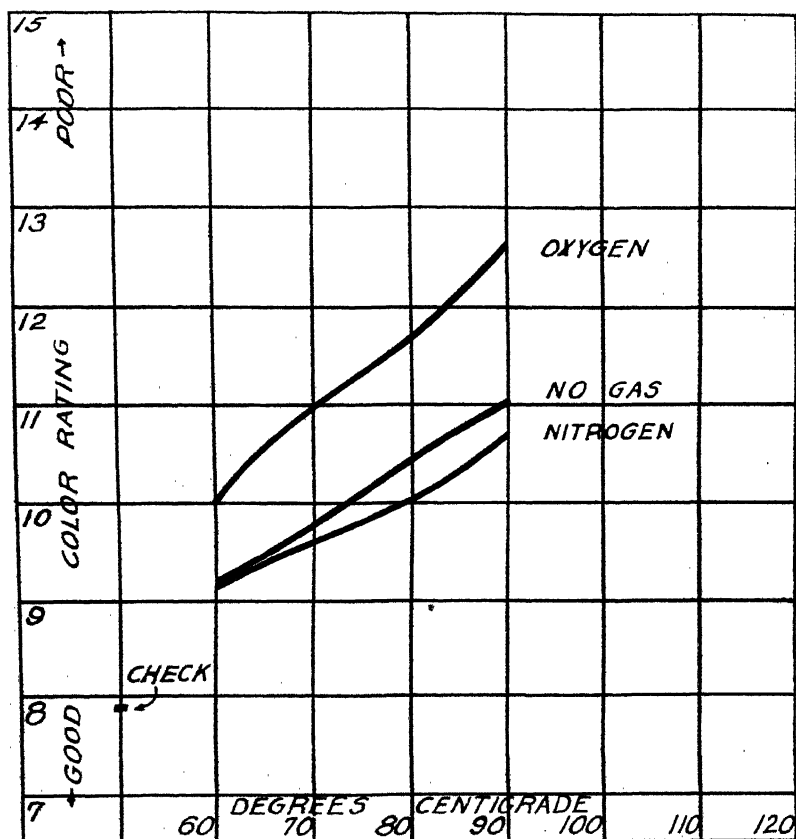


FIG. 3. Color changes in tomato juice as the result of oxygen and nitrogen gas treatments in water bath for 1 hour at 60, 70, 80, and 90 degrees Centigrade.

EFFECT OF OXYGEN AND NITROGEN GASES ON TOMATO JUICE

In order to determine the importance of oxidation on tomato color, gas washing bottles containing 100 cc. of tomato juice were placed in the previous mentioned water bath and gas bubbled through them at the rate of about one bubble per second. Three samples were used at each temperature for the following treatments, (1) no gas or air bubbled through sample, (2) pure oxygen gas bubbled through

sample, and (3) pure nitrogen gas bubbled through sample. The nitrogen gas was passed through alkaline pyrogallol before it was used. These treatments were continued for 1 hour. The curves in Fig. 3 represent the averages of five experiments. Oxygen gas treatment resulted in a decidedly poorer color at all temperatures than either of the other two treatments. The nitrogen treatment represents as great a degree of exclusion of oxygen as it is possible to obtain without resorting to some mechanical method.

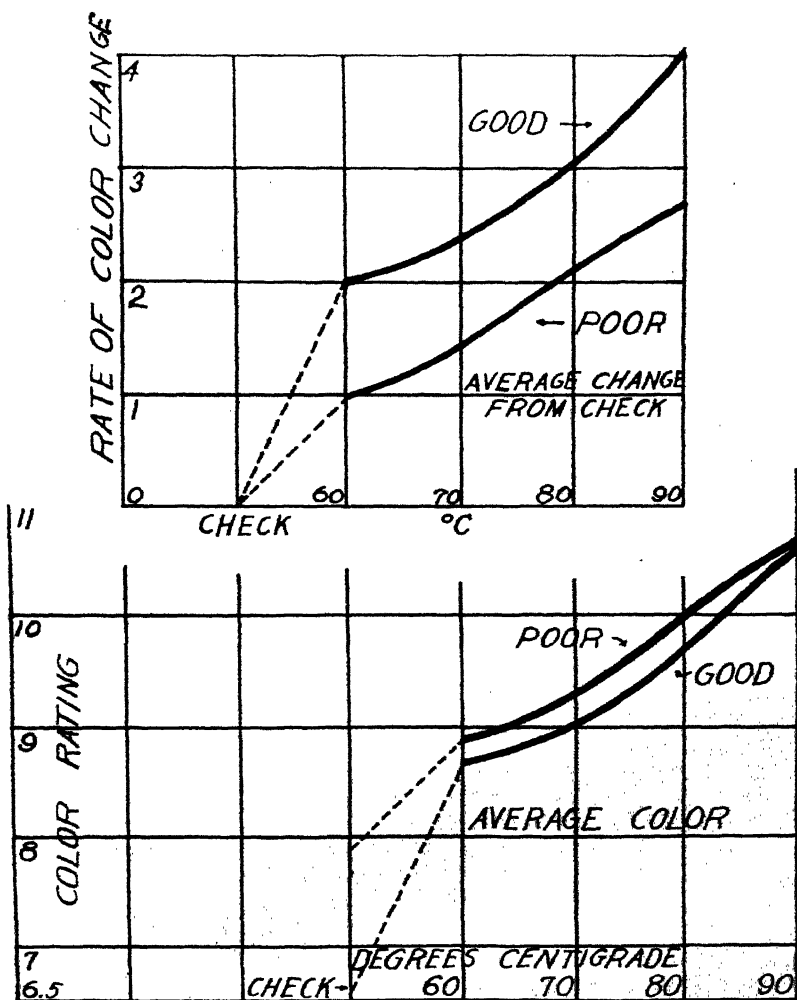


FIG. 4. Color changes in good and poor colored tomato juice as the result of processing in water bath for 1 hour. Results plotted to show actual color as result of treatment and also average change in color from untreated check.

THE EFFECT OF TEMPERATURE ON GOOD AND POOR COLORED JUICE

These experiments were performed on samples of tomato juice which varied in the color of the untreated sample, and although the experiments were planned with different objectives in view, it is desirable and possible to study the effect of temperature as related to the initial color. Color ratings after processing at different temperatures were averaged for four samples which possessed an initial color varying from a color rating of 7.41 to 8.52 as measured by spinning discs, and compared with five samples having an initial color rating varying from 6.48 to 7.01. The results of the average color changes due to different temperatures may be found in Fig. 4. Good colored samples seem to suffer a relatively greater color impairment than poor colored samples, although the final value of the former is still superior. Thus, this change is not of sufficient magnitude to eliminate the desirability of using good colored tomatoes. Further studies of this point are planned.

Oxidation of tomato pigment results in a poorer color, but processing temperatures have a similar effect independent of oxidation.

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The Influence of Inbreeding Upon the Season of Maturity in Cabbage

By O. H. PEARSON, *University of California, Davis, Calif.*

IN the spring of 1931, lines of Copenhagen Market cabbage inbred for several generations were compared with hybrids between them for earliness and plant weight. The seed for these trials was planted January 3, 1931, the seedlings set in 2½-inch pots 3 weeks later, and from there into the field on February 22. Each row consisted of 30 plants and was replicated as many times as plants were available. Insofar as possible each hybrid lot was grown between the parental lines, for direct comparison and to nullify soil differences. Although the soil appeared to be very uniform, the check rows, which were placed at every tenth row, varied across the block as much as 10 days, or 4.5 times their probable error. These checks were highly variable, but there seemed to be a very distinct trend toward early and late maturing areas.

TABLE I—NUMBER OF DAYS TO MATURITY AND TOTAL PLANT WEIGHT IN THREE COMMERCIAL STRAINS OF COPENHAGEN MARKET CABBAGE

Strain	Row	Days	Plant Weight (Grams)
CM-2.....	14	100.7±1.27	1740.0±60.0
	39	104.4±1.77	1603.9±46.9
CM-3.....	13	108.9±1.08	1375.0±58.1
	38	103.2±1.30	1676.7±39.2
	63	93.5±1.69	1875.5±64.4
CM-13.....	12	109.2±1.41	1854.2±65.6
	40	105.1±1.23	1997.5±57.4
	62	99.2±1.13	2388.0±64.4

As each plant came to maturity, as determined by the hardness of the "head," the whole plant was pulled and taken to the field house for records. In many cases not all plants matured. The blocks were gone over every 2 to 4 days from May 17 until July 3, a harvest period of about 7 weeks. The high prevailing temperatures of late June caused the plants to cease growth, and several of the later lines were not harvested. Season was considered as the number of days between planting the seed and the harvesting of the plant.

Three lots of stock seed of Copenhagen Market typical of the strain were included and replicated several times. They are designated as CM-2, CM-3, and CM-13. They are approximately of the same season of maturity, although the replications differ by several days in different parts of the field. In Table I are shown the number of days to maturity and total plant weight of these strains. Not all the data can be presented in this paper due to lack of space, but the results

TABLE II—NUMBER OF DAYS TO MATURITY IN P₁ AND F₁ LINES

Cross No.	Pedigree	Row	Days	D/PE	Odds	Row	Days	D/PE	Odds
1	{ 1-10-15-1-1-5 1-10-15-1-1-5 x 1-2-36-3-2-21 1-2-36-3-2-21	9	111.4±2.01	3.33	37.1:1	32	114.1±.81	5.3	3000:1
		8	103.5±1.26	5.1	1500:1	33	106.3±1.25		
		7	112.0±1.10						
2	{ 1-2-36-3-2-21 1-6-87-2-D-2 x 1-2-36-3-2-21 1-6-87-2-D-2	47	110.8±.52	7.6	1000000:1				
		48	102.8±.91	11.5	∞				
		49	117.0±.82						
3	{ 1-4-41-15-2 1-4-41-15-2 x 1-4-61-1-8-11 1-4-61-1-8-11	29	94.2±.88	4.6	520:1	59	93.2±.86	1.2	1.4:1
		30	104.9±2.19	2.5	9.9:1	60	94.9±1.12	6.9	400000:1
		31	112.2±1.94			61	106.7±1.29		
4	{ 1-4-61-1-8-11 1-13-3-9-1 x 1-4-61-1-8-11 1-13-3-9-1	21	108.2±1.61	2.5	9.9:1				
		22	103.4±1.06	.093					
		23	103.6±1.87						
5	{ 1-6-76-113 1-6-76-113 x 1-6-76-104 1-6-76-104	25	108.0±1.31	.81	8.5:1				
		26	109.6±1.49	2.4					
		27	105.5±.86						
6	{ 1-2-8-1-1-1 1-2-8-1-1-1 x 1-2-36-3-2-4 1-2-36-3-2-4	36	112.6±1.03	1.4	1.9:1	43	115.7±.91	1.9	.4:1
		35	110.6±.94	1.1	1.2:1	44	111.1±1.04	1.5	2.2:1
		34	108.6±1.58			45	108.6±1.32		

TABLE III—PLANT WEIGHT IN P₁ AND F₁ LINES

Cross No.	Pedigree	Row	Plant Weight (Grams)	D/PE	Odds	Row	Plant Weight (Grams)	D/PE	Odds
1	{ 1-10-15-1-1-5. 1-10-15-1-1-5 x 1-2-36-3-2-21 1-2-36-3-2-21.	9	1571.1 ± 44.0	1.5	2.2:1	32	1650.0 ± 78.0	1.26	1.5:1
		8	1473.1 ± 48.2	6.15	30000:1	33	1767.8 ± 51.3		
		7	1107.0 ± 35.1						
2	{ 1-2-36-3-2-21. 1-2-36-3-2-21. 1-6-87-2-D-2 x 1-2-36-3-2-21 1-6-87-2-D-2.	47	1104.2 ± 44.1	9.8	∞				
		48	1756.9 ± 49.5	5.57	7000:1				
		49	1366.7 ± 49.6						
3	{ 1-4-41-15-2. 1-4-41-15-2 x 1-4-61-1-8-11 1-4-61-1-8-11.	29	1435.2 ± 35.2	9.57	∞	59	1825.0 ± 46.5	3.84	100:1
		30	1972.7 ± 43.7	2.89	18.0:1	60	2150.0 ± 70.9	.73	—
		31	2179.4 ± 56.8			61	2219.3 ± 64.5		
4	{ 1-4-61-1-8-11. 1-13-3-9-1 x 1-4-61-1-8-11. 1-13-3-9-1.	21	1935.0 ± 85.7	1.38	1.6:1				
		22	1783.0 ± 69.2	5.46	6000:1				
		23	1337.0 ± 43.5						
5	{ 1-6-76-113. 1-6-76-113 x 1-6-76-104. 1-6-76-104.	25	1258.3 ± 53.3	1.56	2.4:1				
		26	1370.0 ± 47.7	2.23	6.6:1				
		27	1508.0 ± 39.5						
6	{ 1-2-8-1-1-1. 1-2-8-1-1-1 x 1-2-36-3-2-4. 1-2-36-3-2-4.	36	1735.2 ± 49.0	5.23	3000:1	43	1757.7 ± 53.0	2.02	4.7:1
		35	2122.4 ± 55.5	12.15	∞	44	1806.5 ± 45.9	5.9	15000:1
		34	1271.0 ± 71.8			45	1350.0 ± 62.4		

shown in the accompanying tables are typical. In Table II the number of days to maturity of the parents and their hybrids are shown, with the difference divided by the probable error, and the odds of significance. The mean and probable error were calculated by Bessel's formulae, and the odds are taken from Pearl and Miner (7).

From a study of the pedigrees, the crosses involving unrelated lines give an increase in earliness; as the degree of relationship becomes closer the difference between parent and hybrid becomes less. Thus the cross between 1-10-15-1-1-5 and 1-2-36-3-2-21 (cross No. 1) is about a week earlier than either of the parents, which happen to have about the same mean number of days to maturity. Similarly the unrelated lines 1-2-36-3-2-21 and 1-6-8-7-2-D-2 form a hybrid (cross No. 2) much earlier than either parent. However, the hybrid between 1-2-8-1-1-1 and 1-2-36-3-2-4 (cross No. 6) is of the same season as the parents. The hybrid 1-6-76-113 and 1-6-76-104 (cross No. 5) is almost identical in season with its parents.

In Table III the total plant weights of these same parents and F_1 hybrids are shown. In all except cross No. 6 the relations between F_1 and parents are of the same order as in the table for season. However, in cross No. 6, although the season remained the same as the parents, the total plant weight of the F_1 hybrid was significantly greater. Table IV presents these results as difference of the F_1 hybrid from the mean of the parents. Significant increases in weight are only evident in crosses Nos. 2, 6, and 6a and in season only in crosses Nos. 1 and 2.

Earliness in plants may be either (1) genetic in nature, such as differences between strains or varieties, (2) the result of soil or climatic differences, or (3) the result of increased vigor in the plant due to either one or the other of the above reasons. Earliness as a character has been studied in rice by Jones (4); barley, Neathy (6); wheat, Stephens (8); peas, Keeble and Pellew (5); and oats, Caporn (1). Its inheritance has been found to be complex, apparently dependent on several factors, and quantitative in nature. In tomatoes, Hayes and Jones (2) and Wellington (9), and in corn, Jones *et al* (3), increased earliness as well as increased yield has been found to be the result of crossing two varieties. In these cases earliness is apparently the result of the increased vigor of the F_1 plant. In the crosses of cabbage, it could be expected that all three types would be represented. In crosses Nos. 1 and 2, the increase in vigor, as shown in Table III is probably the result of hybrid vigor, or at least a portion is due to that cause since the odds are in the same direction. In cross No. 1 the increase in earliness, which borders upon significance, is probably largely due to genetic reasons, since the increase in weight over the mean of the parents is not significant but the increase in earliness is almost significant (Table IV). In cross No. 2, the increase in size is accompanied by earliness and it is impossible to tell whether the earlier season of the hybrid is due only to vegetative vigor or to a factorial combination.

In crosses Nos. 3 and 4, involving 1-4-61-1-8-11, the results are not so clear cut. This common parent was found to be very variable, possibly an F_2 from a contamination in 1929. The mean for the total weight is high and the line is also late. The hybrids in each case were intermediate both in total weight and season.

Crosses Nos. 5 and 6 are examples of close crosses. Cross No. 5 is between sister plants; weight and season of the hybrids are the same as the parents. Cross No. 6 on the other hand is between two lines originating from the same parent, but separated by four generations. In season, the situation resembles that in cross No. 5, with no difference between parents and hybrid. In weight, however, a very different situation is found. The hybrid is significantly heavier than one parent, and possibly the other. These results would seem to show that in some cases season is a genetic factor, and is not simply a secondary expression of hybrid vigor.

The influence of environment upon season is well known. The response of different plants to the same environment differs; some plants are more sensitive to environmental changes than others. In crosses Nos. 3 and 6 there are good examples of this differential response. (Table II). In cross No. 3 the season of the hybrid in row 30 is almost intermediate, whereas in row 60 the hybrid nearly equals the earlier parent. This portion of the field is earlier ground than that near row 30, as shown by the check rows 31 and 61, but the response of the hybrid to these conditions is much more marked than either parent. For the hybrid the difference is 10.0 ± 2.46 days, for the check 5.5 ± 2.33 days, and for 1-4-41-15-2, 1.0 ± 1.23 days. Response to these apparently more favorable conditions is reflected, though to a less degree and probably with no statistical significance, in the weight of the plants. Even in this case, 1-4-41-15-2 increased 389.8 ± 58.3 grams, a significant amount.

In cross No. 6, a difference in location of seven rows, 21 feet, causes no difference in season, and a very slight difference in weight, as shown mostly by the hybrid as a difference of 315.9 ± 95.1 grams, which is not statistically significant.

From these few data, it appears that season in cabbage is dependent in part upon genetic factors, and that hybridization with resulting increase in vigor is not necessarily accompanied by an earlier time of maturity. Likewise, that environmental differences do not affect all the strains in the same way, and that for a definite test, replications together with check rows are very necessary.

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Thresher Injury in Baby Lima Beans

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ABSTRACT

The complete paper will appear in the Journal of Agricultural Research.

BABY Lima beans are particularly susceptible to thresher injury. While part of this damage may be externally visible, very frequently the injuries are confined to the embryo itself and are not seen until the seeds are germinated. Sometimes the embryos may be so completely shattered within the seed that germination does not occur. In less severe cases the seeds germinate but the seedlings show defects of various kinds, such as bald-head and damage to cotyledons, hypocotyl, and radicle. Hand-shelled beans produce no seedlings of this type. It is possible, however, by mechanical shock to produce such injury in hand-shelled seed.

Some Chemical and Physical Changes Observed in Green Lima Beans Subjected to Various Storage Conditions

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Norfolk, Va.*

THE production of lima beans (*Phaseolus lunatus*), to be marketed in the immature shelled state, is of more importance in the South than in most other sections. Large acreages are also grown for canning purposes. This paper presents some of the physical and chemical relationships observed in a limited number of bean samples, handled in various ways following harvesting. Comparisons are made of beans left on pulled vines, in picked pods, and in a shelled condition, under normal and cold storage temperatures. Data are also presented concerning the storage and handling of shelled beans in practically air-tight cellophane bags.

Henderson bush lima beans, harvested at intervals from September 10 to October 20 were used in the work summarized in this paper. Since it was impossible to use samples of like physiological or chronological age, all white beans were carefully removed from samples stored in a shelled condition, and a proportional amount, at time of sampling, from beans stored on vines and in pods. Beans on vines were stored in a shaded place in the open; those in pods, in shallow baskets in the laboratory and in an electric refrigerator. Shelled beans in pans, and under anaerobic conditions in tied cellophane bags were placed under the same temperature conditions as those in pods. The temperature of the refrigerator varied from 0 to 2 degrees C., and that of the open storage from 24 to 30 degrees C. Humidity in the refrigerator varied from 50 to 60 per cent. No record was kept of the open storage humidity. Data on whitening, loss in weight, and spoilage were taken.

Dry weight, total and reducing sugars, total polysaccharides, and total and insoluble nitrogen were determined on duplicate 50-gram samples as noted in a previous work (6). Starch was determined on 100-mesh material essentially as outlined by Boswell (5). Crude fiber was determined on 40-mesh material as outlined by the official methods (14). To be comparable with other fiber determinations, percentages of fiber were adjusted to a 20-mesh basis by multiplying by the factor 1.13. This factor was found by dividing the amount found in a 20-mesh sample by that found in a 40-mesh sample of the same material.

RESULTS AND CONCLUSIONS

The results are presented in Tables I to V. Table I shows the relative weight of seeds based on weight of fruits (pods) under different storage conditions. Although there are some variations in the

seed-fruit ratios, in general they remain fairly constant. This fact justified the use of the fruit weight loss in estimating loss in weight of seeds stored in pods.

TABLE I—THE EFFECT OF STORAGE TREATMENT ON THE SEED/FRUIT RATIO OF GREEN LIMA BEANS

Storage Period (Hours)	Ratio			Temperature ² (Degrees F)	Rainfall (Inches)
	On Vines	In Pods N.T. ¹	In Pods C.T.		
24	.435	.612	.446	80.8	.60
48	.401	.447	.360	78.5	
72	.466	.450	.444	75.0	

¹N.T.—Normal Temperature. C.T.—Cold Temperature.

²Temperature average (min. and max.) for 24 hour period.

TABLE II—THE EFFECT OF STORAGE TREATMENT ON THE PER CENT LOSS IN WEIGHT AND WHITENING OF GREEN LIMA BEANS

Sample No.	Storage		Per cent White Seeds	Loss in Weight
	Period (Hrs.)	Condi- tion ¹		
At Time of Harvest				
1	0	—	8.66	.0
On Vines				
3	24	N.T.	35.00	—
5	48	N.T.	29.54	—
6	72	N.T.	40.00	—
In Pods				
7	24	N.T.	49.84	4.9
8	48	N.T.	60.90	22.3
9	72	N.T.	73.20	27.8
10	24	C.T.	18.26	3.0
11	48	C.T.	8.00	5.7
12	72	C.T.	15.95	9.0

Sample No.	Storage		Per cent White Seeds	Loss in Weight
	Period (Hrs.)	Condi- tion ¹		
Shelled Beans				
14	24	N.T.	44.58	10.41
16	48	N.T.	72.60	16.40
—	72	N.T.	—	25.53
18	24	C.T.	10.02	3.74
20	48	C.T.	12.04	7.22
21	72	C.T.	13.67	12.03
Stored in Cellophane ²				
22	4p.c.-20 hrs.		9.70	.0
23	4p.c.-20-4N.T.		16.52	1.15
24	2N.T.-46		11.44	1.25
25	2p.c.-46		9.81	.75
26	4p.c.-44		10.03	.75
27	4p.c.-44-4N.T.		15.00	2.00
28	4p.c.-68		17.79	1.50
29	4p.c.-44-4N.T.			
	-20		20.95	1.50

¹Abbreviations. N.T.—Normal Temperatures, C.T.—Cold Temperatures, p.c.—precooled.

²All samples stored under cold temperature conditions unless otherwise noted.

Note: Normal Temperatures 24°–30°C. Cold Temperatures 0°–2°C.

The data in Table II show that the greatest loss in weight in lima beans does not always occur during the first 24 hours as other workers (3, 4, 11) have found occurring in some other vegetables. However, the first day is responsible for the largest increase in white beans, which is partly accounted for by the largest and oldest beans being first to whiten. In whitening, the sprout or germ end of the bean loses its chlorophyll first, a fact which may be correlated with its higher respiratory rate as pointed out by Bailey (2). The low

TABLE III—THE EFFECT OF STORAGE TREATMENT ON THE CONDITION AND PER CENT LOSS IN WEIGHT OF GREEN LIMA BEANS

Condition	Normal Temperature				Cold Temperature					
	Cellophane		Open		Cellophane		p.c. 2 hours ³ Cellophane		p.c. 24 hours Cellophane	
	Loss in Wt.	Condition ¹	Loss in Wt.	Condition	Loss in Wt.	Condition	Loss in Wt.	Condition	Loss in Wt.	Condition
Storage Period (Days)										
1	0.3	V.G.	8.9	V.G.	0.0	V.G.	0.3	V.G.	3.3	V.G.
2	0.7	V.G.	14.8	G.	0.2	V.G.	0.6	V.G.	3.5	V.G.
3	1.4	G.	21.1	P.	0.3	V.G.	0.6	V.G.	3.8	V.G.
5	3.1	I.	27.7	I.	1.3	V.G.	2.3	V.G.	4.7	V.G.
6	—	—	—	—	1.6	G.	2.9	G.	5.3	G.
7	—	—	—	—	1.9	F.	3.9	F.	6.0	F.
8	—	—	—	—	2.9	F.	4.7	F.	6.7	F.
9	—	—	—	—	3.6	P.	5.9	F.	7.4	F.
10	—	—	—	—	4.4	P.	6.8	F.	8.3	P.
12	—	—	—	—	5.9	I.	8.6	F.	9.9	P.
13	—	—	—	—	6.7	I.	9.6	F.	10.7	P.
14	—	—	—	—	7.7	I.	10.4	F.	11.4	P.
17	—	—	—	—	10.3	I.	13.6	I.	14.3	I.
20	—	—	—	—	13.1	I.	17.1	I.	16.7	I.

¹Abbr. V.G.—as fresh state. G.—some whitening or drying. F.—seeds damp. P.—damp, brown, or some odor. I.—inedible.
²p.c.—precooled.

per cent of white beans (Sample No. 11) is a discrepancy due to sampling, but it is worth noting in that it is associated with a very low per cent of polysaccharides other than starch (Table V).

TABLE IV—COMPOSITION OF GREEN LIMA BEAN SEEDS IN PER CENT OF FRESH WEIGHT AT TIME OF HARVEST

Sample No.	Storage		Initial Wt. Sample	Dry Mat-ter	Total Sugar	Starch	Total Carbohy- drates	Total Nitrogen	Crude Fiber
	Period (Hours)	Condition ¹							
A At Time of Harvest									
1	0	—	50.00	33.48	2.06	11.63	16.84	1.42	1.99
C Stored in Pods									
7	24	N.T.	52.58	35.85	.83	11.90	17.86	1.59	—
8	48	N.T.	64.35	28.99	.72	10.31	15.17	1.26	1.91
9	72	N.T.	69.25	28.76	.72	9.15	14.33	1.28	—
10	24	C.T.	51.55	35.92	1.53	12.02	19.71	1.35	—
11	48	C.T.	53.02	34.87	1.58	12.58	16.90	1.34	2.07
12	72	C.T.	55.00	35.38	1.60	11.92	19.55	1.41	—
D Shelled Beans									
14	24	N.T.	55.81	33.82	.63	12.01	17.94	1.49	—
16	48	N.T.	60.00	33.23	.88	10.80	16.50	1.44	2.15
18	24	C.T.	51.94	36.11	1.28	13.27	18.87	1.51	—
20	48	C.T.	53.90	35.38	1.49	11.28	18.92	1.45	2.12
21	72	C.T.	56.84	34.81	1.40	12.03	17.90	1.32	—
E Shelled Beans Stored in Cellophane ²									
22	4 p.c.-20 hrs.		50.00	35.05	1.55	11.47	18.68	1.45	2.04
23	4 p.c.-20-4 N.T.		50.58	35.64	1.23	12.94	20.34	1.51	—
24	2 N.T.-46		50.63	34.37	1.41	11.55	18.27	1.51	—
25	2 p.c.-46		50.84	34.57	1.58	11.61	19.73	1.41	—
26	4 p.c.-44		50.37	35.70	1.31	12.30	19.03	1.50	—
27	4 p.c.-44-4N.T.		51.02	35.73	1.36	12.70	18.94	1.54	—
28	4 p.c.-68		50.76	34.81	1.33	11.59	18.32	1.49	2.23
29	4 p.c.-44-4N.T.-20		50.76	36.38	1.15	12.67	19.84	1.54	—
F Storage Changes in Open and Cellophane Containers									
30	60 hrs. open N.T.		67.34	30.28	.77	10.05	14.49	1.32	1.95
31	60 hrs. cello. N.T.		50.50	32.04	1.31	11.27	16.06	1.37	1.92
32	60 hrs. open C.T.		56.90	32.78	.88	11.40	16.98	1.38	1.88
33	60 hrs. cello. C.T.		50.25	32.63	.89	11.32	16.15	1.35	2.00
34	10 days cello. C.T.		51.39	36.45	1.24	12.38	19.69	1.54	2.20
35	20 days open C.T.		128.63	35.37	1.15	12.91	19.43	1.41	1.89
36	20 days cello. C.T.		68.96	34.07	.84	12.41	18.49	1.32	1.87

¹Abbreviations. N.T.—Normal Temperature, C.T.—Cold Temperature, p.c.—precooled.

²All samples in cellophane stored under cold temperature conditions unless otherwise noted.

In Table III the effects of storage in cellophane are given. Cellophane is excellent in preventing loss of moisture but does not prevent whitening. Beans stored in cellophane become sticky after several days at normal temperatures and after 10 days at cold temperatures. Cooking tests were made on beans stored for 60 hours in the open and in cellophane under normal and cold temperatures. Their

edible quality was ranked in the following descending order: (1), lot stored in open under cold temperatures, (2) lot stored in cellophane under cold temperatures, (3) lot stored in open under normal temperatures, and (4) lot stored in cellophane under normal temperatures. Both samples stored in cellophane seemed tougher and had a slightly disagreeable taste, due perhaps to anaerobic changes in the proteins during the storage period. Additional evidence is necessary to recommend or condemn the use of cellophane in the marketing of beans.

The chemical changes occurring are outlined in Tables IV and V. In Table IV the results are expressed in terms of per cent at time of harvest and, therefore, indicate actual gains or losses in the various materials, so are most significant from a physiological standpoint. This table was calculated from the figures in Table V using the losses in weight found in Table II. In Table V the results are in terms of per cent at time of sampling and show the status of each lot at the end of their respective storage periods, thus portraying edible quality.

Dry Matter: Increases in dry matter (Table IV) are due to inaccuracies in sampling or in estimating the losses in weight. The lack of any large dry matter losses is probably due to the relative state of maturity and lack of moisture content of these seeds. McGinnis (13) noted that most of the carbohydrate losses of wheat occurred before desiccation began, while the grain contained over 40 per cent moisture. The lack of any great change in dry weight of the beans stored in cellophane is probably due to an oxygen deficiency. Bailey (2) in a study of stored grains, noted that respiration was reduced in an oxygen free atmosphere, the ratio to that occurring in a normal atmosphere being about 1 to 2.5. Based on actual content at time of sampling (Table V) dry matter increases, due to moisture losses that were proportionally greater than dry weight losses.

Starch: In Table IV the increases in starch during the first 24-hour period may possibly be accounted for in sugar condensation. At the end of the successive periods, respiration has in general caused some declines in the amount present. Beans held in pods at normal temperatures show more rapid starch decreases than those kept under any other condition of storage.

Total sugars: Total sugars decrease most rapidly during the first twenty-four hours, and then reaching the minimum, as noted by Appleman (1), fail to show any significant additional losses (Table IV). This minimum percentage of sugar is larger at cold than at normal temperatures, with the exception of beans stored on the vine. Vine storage does not seem to be as conducive to rapid sugar losses as other normal temperature storage conditions.

Nitrogen: Total and insoluble nitrogen tend to increase and soluble nitrogen tends to decrease during the storage period (Table V). However, actual losses in total nitrogen occur (Table IV); but not at as rapid a rate as that of carbohydrates.

TABLE V.—COMPOSITION OF GREEN LIMA BEAN SEEDS IN PER CENT OF FRESH WEIGHT AT TIME OF SAMPLING

Sample No.	Storage		Dry Matter	Total Sugars	Starch	Other Polysaccharides	Total Carbohydrates	Insoluble Nitrogen	Soluble Nitrogen	Total Nitrogen	Crude Fiber
	Period (Hours)	Condition ¹									
A											
1	0	—	33.48	2.03	11.63	3.17	16.83	1.27	.15	1.42	1.99
B											
At Time of Harvest											
Stored on Vines											
2	12	N.T.	37.35	1.40	13.97	3.46	18.83	1.56	.12	1.68	—
3	24	N.T.	39.74	1.32	12.84	5.84	19.00	1.53	.12	1.65	—
4	36	N.T.	32.74	1.99	9.97	4.39	16.35	1.25	.23	1.48	—
5	48	N.T.	37.21	1.10	12.81	4.28	18.19	1.47	.13	1.60	2.46
6	72	N.T.	40.59	1.36	13.07	6.07	20.50	1.61	.20	1.81	—
C											
Stored in Pods											
7	24	N.T.	37.71	.88	12.52	5.39	18.79	1.49	.19	1.68	—
8	48	N.T.	37.32	.94	13.28	4.81	19.03	1.53	.10	1.63	2.46
9	72	N.T.	39.85	1.01	12.67	6.17	19.85	1.75	.03	1.78	—
10	24	C.T.	37.04	1.58	12.40	6.35	20.33	1.41	.15	1.56	—
11	48	C.T.	36.98	1.68	13.35	2.89	17.92	1.32	.11	1.43	2.20
12	72	C.T.	38.92	1.77	13.12	6.62	21.51	1.49	.07	1.56	—
D											
Shelled Beans											
13	12	N.T.	34.21	.79	12.33	3.61	16.73	1.35	.16	1.51	—
14	24	N.T.	35.90	.78	12.71	3.86	17.35	1.42	.22	1.64	—
15	36	N.T.	35.08	.78	11.18	5.10	17.06	1.46	.14	1.60	—
16	48	N.T.	39.88	1.06	12.96	5.78	19.80	1.63	.10	1.73	2.59
17	12	C.T.	33.81	1.88	11.80	3.42	17.10	1.27	.22	1.49	—
18	24	C.T.	37.52	1.33	13.79	4.48	19.60	1.48	.09	1.57	—
19	36	C.T.	35.70	1.82	10.67	5.77	18.26	1.67	.00	1.67	—
20	48	C.T.	38.15	1.61	12.17	6.61	20.39	1.41	.16	1.57	2.32
21	72	C.T.	39.58	1.60	13.68	5.06	20.34	1.43	.08	1.51	—

Shelled Beans Stored in Cellophane²

Shelled Beans Stored in Cellophane ^a										
		35.05	1.55	11.47	5.65	18.67	1.31	.14	1.45	2.04
22	4 p.c.-20 hrs.	36.06	1.25	13.10	6.23	20.58	1.41	.12	1.53	—
23	4 p.c.-20-4N.T.	34.81	1.43	11.70	5.73	18.86	1.30	.22	1.52	—
24	2 N.T.-46	35.19	1.61	11.82	6.66	20.09	1.39	.05	1.44	—
25	2 p.c.-46	35.97	1.32	12.40	5.46	19.18	1.50	.02	1.52	—
26	4 p.c.-44	36.46	1.39	12.96	4.94	19.29	1.39	.20	1.59	—
27	4 p.c.-44-4 N. T.	35.35	1.36	11.77	5.52	18.65	1.33	.19	1.52	2.11
28	4 p.c.-68	36.94	1.17	12.87	6.11	20.15	1.43	.14	1.57	—
29	4 p.c.-44-4 N.T.-20									

Storage Changes in Open and Cellophane Containers

F		40.79	1.04	13.54	4.93	19.51	1.63	.15	1.78	2.63
30	60 hrs. open N.T.	32.37	.14	11.39	4.71	16.24	1.21	.18	1.39	1.94
31	60 hrs. cello. N.T.	37.31	1.01	12.98	5.33	19.32	1.46	.11	1.57	2.15
32	60 hrs. open C.T.	32.80	.90	11.38	3.95	16.23	1.24	.12	1.36	2.02
33	60 hrs. cello. C.T.	37.47	1.28	12.73	6.16	20.17	1.42	.17	1.59	2.27
34	10 days cello. C.T.	91.01	2.96	33.22	13.82	50.00	3.27	.26	3.63	4.88
35	20 days open C.T.	46.99	1.17	17.12	7.21	25.50	1.69	.14	1.83	2.58
36	20 days cello. C.T.									

Abbreviations. N.T.—Normal Temperature. C.T.—Cold Temperature. p.c.—precooled.

²All samples in cellophane stored under cold temperature conditions unless otherwise noted.

Crude Fiber: There is very little change in actual amount of fiber throughout the storage period (Table IV), however, shelled beans have some tendency to increase in fiber over the period of observation. Large moisture losses tend to increase the proportionate amounts of fiber in beans stored under normal temperatures (Table V). The actual amounts found and changes based on the fresh and dry weight agree with the results obtained by Dubois (9).

The data show that lima beans are physiologically older than other vegetables used in the green state. No test on any of the samples indicated more than a slight trace of reducing substances. The high percentage dry weight, low percentage total sugar, and lack of rapid response to storage treatments, along with the results obtained by other workers (3, 4, 7, 8, 10, 11, 12) substantiate the above statement. However, this work indicates that there may be changes in chemical composition associated with rapid whitening during the first day after harvest which were not apparent in this work, due to the length of initial storage period and variability of the samples used. A more careful study of the changes occurring in the polysaccharide content should be of some value.

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Experiments With Ultra-Violet Transmitting Glasses for Growing Vegetable Plants in Coldframes

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IN the past few years a great amount of study has been devoted to the effects of different wave-lengths of light upon plant growth. Both in this country and abroad numerous investigations have been made relative to the possible economic value of growing plants under certain window glasses which transmit a portion of the ultra-violet light of the sun. The results are somewhat inconsistent and conflicting, but in general it appears that there is no very marked advantage in using ultra-violet transmitting glasses as compared with common glass.

A number of commercial glass firms in this country have been very much interested in determining whether plants grown under their respective glasses would make sufficiently larger growth or better quality than under common glass to justify recommending those special glasses for general plant-growing purposes. Three manufacturers and dealers submitted to the authors, quantities of their respective products sufficient to glaze several standard sash which were used in the studies reported herein.

In this work no attempt was made to conduct a technical study of the effect of various wave-lengths of light upon plant growth under controlled conditions. The object was to determine whether appreciable growth differences would be produced among plants grown in an ordinary coldframe, covered with various glasses, and managed in a manner comparable with commercial practice.

METHODS

Temporary coldframes were used about 100 feet long, in locations of unobstructed light. Individual plots were 6 by 9 feet and covered with three sash. Treatments were usually in duplicate, but in the study of Vita-Glass alone there were four replications. On account of insufficient glass only one plot of Uviol-Jena could be included. At least three control plots of common glass were used in each test, these being located near each end and near the middle of the frame. The order of replicate treatments was reversed in different parts of the frame to check out any definite gradient in soil conditions that might have been present. Treatments were compared with the adjacent control unless the treated plot was the middle of the three plots between controls, in which instance the treatment was compared with the mean of the two equidistant controls.

Data were recorded upon each individual plant in each plot, and the results expressed as the mean per plant for each plot, together with the probable error.

Marglobe tomato seeds were sown in the frame under the respective glasses March 28, 1929, and spotted 6 by 9 inches April 23 and 24. The glass was kept over the plants almost continually until the yield records were taken; but after May 10 the sash were propped up much of the time to afford ventilation. It was removed at intervals while watering the plants. The plants were cut off at the soil surface, weighed, and the height determined on June 14.

TABLE I—GROWTH OF TOMATO PLANTS UNDER COMMON GLASS AND VITA-GLASS. SPRING, 1929

Comparison Number	Common Glass	Vita-glass	Difference*
Plant Weight in Grams			
1	20.94±1.07	19.55±1.15	-1.39±1.57
2	20.00±.96	22.87±1.28	+2.87±1.60
3	24.45±.89	27.12±1.13	+2.67±1.44
4	33.03±1.32	26.94±1.12	-6.09±1.73
5	13.56±.77	16.66±.80	+3.10±1.11
Total	22.61±.57	22.64±.54	+ .03±.79
Plant Height in Inches			
1	12.69±.29	11.40±.26	-1.29±.39
2	10.93±.33	11.85±.28	+.92±.43
3	13.37±.20	14.65±.21	+1.28±.30
4	11.81±.22	12.07±.31	+.26±.38
5	15.21±.15	13.93±.19	-1.28±.24
Total	12.80±.11	12.78±.11	-.02±.16

*Increase or decrease of treatment compared with common glass.

In 1930, Ruby Giant pepper seeds were sown in the frame under the respective glasses May 5, and spotted 6 by 6 inches on June 3. The glass was kept over the plants almost continually, but of course was propped up during very warm weather to provide ventilation. The plants were cut off at the surface of the soil and weighed July 1.

In 1931, seeds sown in the frames the middle of April failed to grow satisfactorily. Seeds were then sown in flats in the greenhouse and the flats placed under the respective glass as soon as the seed had started to germinate well. The plants were spotted 6 by 6 inches on May 19 and growth data recorded July 1. The frames were managed as described above.

Seeds of Scarlet Turnip White Tip radish were sown by spotting 6 by 6 inches in the frame Oct. 16, 1930. The groups of plants were thinned to a single plant on Oct. 28. The plants were harvested and weighed, roots and tops separately, on Jan. 2 and 3, 1931.

RESULTS

Table I shows that there was a significant difference in weight of plants grown under Vita-Glass and common glass in only one of five comparisons. In this instance the Vita-Glass plot produced smaller plants than common glass, but when considered with the

other comparisons it can only be concluded that the common glass and Vita-Glass produced plants of practically the same weight.

Differences in plant height were inconsistent among the several comparisons and wholly without significance in the totals of all plots.

It is recognized that pepper plants are not commonly grown by sowing seed in coldframes, but it was believed that the pepper

TABLE II—MEAN WEIGHT OF PEPPER PLANTS GROWN UNDER COMMON GLASS AND ULTRA-VIOLET TRANSMITTING GLASSES

Comparison Number	Kind of Glass in Treatment	Common Glass Wt. in Gms.	Treatment Wt. in Gms.	Difference ¹ Wt. in Gms.
Spring 1930				
1	Vita-Glass	13.78±1.27	16.37±.80	+2.59±1.50
2	Vita-Glass	21.67±1.00	24.55±1.02	+2.88±1.43
3	Helio-Glass	19.74±.73	16.37±.83	-3.37±1.11
4	Helio-Glass	23.68±.68	29.92±.88	+6.24±1.11
5	Uviol-Jena	25.69±.92	13.33±.59	-12.36±1.09
1 and 2	Vita-Glass	17.72±.81	20.64±.65	+2.74±1.04
3 and 4	Helio-Glass	20.38±.62	23.14±.59	+2.76±.86
Spring 1931				
1	Vita-Glass	12.22±.47	16.31±.71	+4.09±.85
2	Vita-Glass	12.34±.57	11.88±.68	-.46±.89
3	Helio-Glass	17.23±.67	15.98±.75	-1.28±1.00
4	Helio-Glass	14.78±.44	11.31±.49	-3.47±.66
5	Uviol-Jena	17.23±.67	15.42±.62	-1.81±.91
1 and 2	Vita-Glass	12.28±.37	14.09±.49	+1.81±.61
3 and 4	Helio-Glass	14.78±.44	13.64±.45	-1.14±.60

¹Increase or decrease of treatment compared with common glass.

would be useful in determining differences in plant responses to these various glasses on account of its supposed high temperature and light requirements. Even though the seeds were sown relatively late, germination could not be obtained earlier as proved by unsuccessful trials. The plant is tolerant to high temperature and was uninjured by being grown under glass in warm weather except where some leaves touched the glass near the lower side of the frame.

Table II shows a slightly significant increase in size of pepper plant grown under Helio-Glass in 1930. This is of quite questionable significance because comparison No. 3 showed a decrease and No. 4 an increase. In 1931 comparison No. 4 with Helio-Glass showed a significant decrease below common glass but comparison No. 3 was without significant difference, as was the total of both comparisons.

There was no significant difference between plants grown under Vita-Glass and common glass in 1930 although the former tended to produce slightly greater weight. There was a small and slightly significant greater weight of plant produced under Vita-Glass in 1931, but one of the two comparisons showed a lower weight,

thereby rendering questionable the value for the total of the two comparisons.

Plants grown under Uviol-Jena Glass were significantly smaller than under common glass in 1930 but there was no significant difference in 1931. The cause of unsatisfactory growth under this glass in 1930 is unknown but should hardly be ascribed to the glass.

TABLE III—MEAN WEIGHT OF RADISH PLANTS GROWN UNDER COMMON GLASS AND ULTRA-VIOLET TRANSMITTING GLASSES. FALL 1930

Comparison Number	Kind of Glass in Treatment	Common Glass (Wt. in Gms.)	Treatment (Wt. in Gms.)	Difference ¹ (Wt. in Gms.)
Weight of Plant Tops				
1	Vita-Glass	1.87±.10	3.20±.16	+1.33±.19
2	Vita-Glass	3.25±.12	3.36±.12	+ .11±.17
3	Helio-Glass	3.84±.17	3.91±.16	+ .07±.23
4	Helio-Glass	3.54±.17	3.96±.17	+ .42±.20
5	Uviol-Jena	3.84±.17	2.61±.09	—1.23±.19
Weight of Roots				
1	Vita-Glass	2.72±.18	4.02±.17	+1.30±.25
2	Vita-Glass	3.47±.19	4.29±.18	+ .82±.26
3	Helio-Glass	4.69±.23	5.04±.27	+ .35±.35
4	Helio-Glass	4.08±.16	4.65±.22	+ .57±.26
5	Uviol-Jena	3.47±.19	3.20±.14	— .27±.24
1 and 2	Vita-Glass	3.21±.14	4.17±.14	+ .96±.20
3 and 4	Helio-Glass	4.08±.16	4.84±.17	+ .76±.23

¹Increase or decrease of treatment compared with common glass.

A crop of radishes was grown in a coldframe in the fall of 1929 but the data obtained were extremely variable on account of parts of the frame being shaded at certain times on days of sunshine.

Data obtained from a crop grown in the fall of 1930 are presented in Table III. The tops of the radishes had been injured by cold before the records were taken, but the roots were sound. In general, there was no significant difference in weight of tops produced under common glass and ultra-violet transmitting glass.

The plot total comparisons of both Vita-Glass and Helio-Glass show small but significantly greater root weights than produced under common glass. The difference in favor of Vita-Glass in comparison No. 1 appears to be due in part to the abnormally low yield of the control; however, the test and control were immediately adjacent and so should be comparable. The small differences in the single plot comparisons with Helio-Glass are not significant, but when the plot totals are considered a small and significant difference is apparent. The comparison of Uviol-Jena Glass and common glass was without difference, but was based on only a single plot.

DISCUSSION

Comparison of glasses in small cold-frame plots is subject to severe limitations and disturbing factors; but these same limitations and disturbing factors are operative under practical growing conditions

and will tend to eliminate differences in environment that might be produced under these various glasses. The panes in coldframe and hotbed sash very readily accumulate a film of dirt and grime which interferes with light transmission, especially if straw, mats, or other material is placed over the glass during cold periods. Films or droplets of water will at least partly absorb or screen out ultra-violet light. The plants cannot always be kept covered tightly for the frames must be ventilated, and this will diminish temperature differences that might be developed; also the frames must be uncovered for watering the plants at intervals.

These considerations together with the results obtained in the present study as well as the work of others should justify the conclusion that for at least a considerable number of species or varieties, ultra-violet transmitting glasses are of no significant advantage over common glass for use in coldframes. It is only fair to state that no significant disadvantage has been shown, and that if these glasses can be obtained at prices comparable with those of good grades of common glass they should be quite as satisfactory.

Studies of the Hardiness of Plants: A Modification of the Newton Pressure Method, For Small Samples

By S. T. DEXTER, *Chicago, Ill.*

ABSTRACT

The complete paper will appear in the *Journal of Plant Physiology*.

PREVIOUS work done by Dexter *et al.*, has shown that the injury to frozen plants may be estimated by determining the degree of exosmosis of mineral matter from the tissue into distilled water. The concentration of the mineral in the water, in this test, was measured with electrical conductivity methods. In this way the relative hardiness of samples was determined. Newton has shown that the hardiness of winter wheat is correlated with its ability to retain its sap, when subjected to pressure. The volume of sap expressed from a large sample of leaves was measured in a graduate.

The present paper reports an experiment in which the two previous methods are compared; the Newton method is modified so that small samples can be used. One-gram samples of wheat leaves were wrapped in ashless filter paper, and protected from contamination with a flap of sheet rubber. Each sample, in its wrapper, was placed between thick rubber pads in the press cylinder and subjected to pressure for a period of one minute. Pressures from 1000 to 10,000 pounds per square inch were used. After pressing, the pad of paper and leaf tissue was removed from the cylinder, the paper unwrapped, and the tissue and paper placed in a large test tube. To the test tube, a specified quantity of distilled water was added, and the mineral matter was permitted to diffuse from the paper and the tissue. The mineral concentration of the resulting solution was determined electrometrically, at intervals up to 20 hours.

It was shown that the amount of mineral matter diffusing from the paper pad, alone, was greater in the case of tender varieties, and less with harder ones. When the residual tissue, only, was extracted, similar results were obtained. If both were extracted, together, the results were additive. In all cases, hardened tissues were used.

Greater pressure caused greater expression of sap, and greater injury to the tissue, as measured by outward diffusion of electrolytes, in both hardy and tender varieties.

The amounts of mineral obtained from the tissues of hardy and tender varieties, as a result of pressure treatment, were almost precisely proportional to the amounts obtained when the tissue was frozen rather than pressed. Pressure injury and freezing injury showed very close correlation.

While plants of tender and hardy varieties could be distinguished by either freezing or pressing, with subsequent exosmosis, it was

shown that they could not be so distinguished when the plants were killed by heat, by ethyl ether, or by grinding.

Considerable care must be exercised in growing plants for such tests, since, in a given variety, a significant range in hardiness was found under varying environmental conditions. Plants partly shaded for a week were found to be less hardy than plants receiving full light. Plants growing in a well-worked soil, which favored a vegetative type of development, were found to be less hardy than those growing in a compacted soil, where growth was slower.

Reducing the Day Length of Chrysanthemums for the Production of Early Blooms by the Use of Black Sateen Cloth

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

THIS paper deals with the time of day most effective in darkening of chrysanthemums for early blooms, length of time of darkening necessary for best results, part of the plant affected, number of successive nights of darkening necessary, possibilities of producing a succession of bloom by a succession of darkening treatments and the possibilities of outdoor production of early blooms by darkening.

The cuttings of the varieties used for the test were taken during the first 10 days of March. The plants were benched June 20, from 3-inch pots. The planting distance was $7\frac{1}{2} \times 8\frac{1}{2}$ inches. The culture of the plants was that of common commercial practice. Standard varieties were grown two flowers to a plant and pompons pinched the last time the week following benching.

The length of day was reduced by the use of a cheap grade of black sateen cloth over a frame of $1 \times 1\frac{1}{2}$ inch boards and number 14 wire. This resulted in a tight dark chamber, and only the small amount of light which would pass through the cloth was admitted.

RESULTS

Several varieties of both standard and pompon chrysanthemums were darkened at 6 o'clock at night and the cloth removed at 7 o'clock in the morning, starting July 15 and continuing each night until the buds were showing color on all varieties. At Ithaca during this period of the year the sun rises at about 5 a. m. and sets at about 8 p. m. The results are shown in Tables I and II.

The time of bloom of the varieties used was advanced from 39 to 57 days depending on the variety. The stem length was less than check in all cases with standard and pompon varieties. All buds produced on standard varieties under treatment were terminals. The diameter of the flower on some varieties was reduced while that of others was increased as a result of the treatment. The darkening caused a great increase in the number of stems per plant, of pompon varieties. In many cases this was double the check plot. The number of flowers per stem was decreased. The effect of short days on the branching of plants has been reported by Tincker (3) and Garner and Allard (2).

TIME OF DAY FOR DARKENING

Twenty-five plants of each of the varieties Bokhara, Chas. Maynard, Rodell and Pink Dot were placed in each of five plots. The treatments were started July 15 and continued until September 3.

The treatments and results with Bokhara are shown in Table III. Other varieties reacted in similar manner, the data being omitted to conserve space.

TABLE I—EFFECT OF REDUCED LIGHT UPON STANDARD VARIETIES

Variety	Treatment	Buds Taken	Color Showing	Date First Cut	Days Before Check	Average Stem Length (Inches)	Average Flower Diameter (Inches)
Chas. Rager...	Darkened Check	A-10 S-21	A-28 O-24	S-14 N-10	57	33.9 65.0	4.3 5.3
Friendly Rival	Darkened Check	A-10 S-20	A-28 O-24	S-21 N-7	47	21.1 59.5	4.6 5.4
Gold Lode....	Darkened Check	A-5 S-11	A-18 S-29	A-26 O-13	48	23.8 58.0	3.9 4.7
Mrs. D. F. Roy	Darkened Check	A-10 S-10	A-31 S-28	S-21 N-3	43	22.3 49.6	4.5 5.2
October Rose..	Darkened Check	A-5 S-14	A-20 O-5	S-8 O-23	45	35.7 66.6	5.0 4.8
Quaker Maid..	Darkened Check	A-10 S-6	A-18 O-2	S-1 O-13	42	33.7 51.4	4.4 4.0
Rose Chocard.	Darkened Check	A-10 S-14	A-26 O-10	S-14 O-26	42	20.6 38.5	3.6 4.1
Silver Sheen...	Darkened Check	A-5 S-14	A-21 O-5	S-8 O-26	48	28.9 61.1	4.5 4.7
Snow White...	Darkened Check	A-25 S-10	S-14 S-30	S-29 N-7	39	25.7 46.7	3.9 4.7
Thanksgiving Pink	Darkened Check	A-17 S-5	S-14 O-5	O-2 N-16	45	26.6 55.2	4.6 4.8

¹A = August; S = Sept.; N = Nov.; O = Oct.

Table III clearly shows that darkening with the black sateen cloth for a period of 4 hours per day distributed equally at both ends of the day or from 6 p. m. to 7 a. m. was more effective in hastening blooms than the same length of time of darkening in afternoon or from 4 p. m. to nightfall, and this was in turn more effective than the same period of darkening in the morning. All three treatments produced blooms before the check plot which was in full bloom about 2 days before the treatment during the middle of the day or from 9 a. m. to 1 p. m. The superior value of morning light for the promotion of growth has been pointed out by Espino and Pantaleon (1). The plants did not bloom uniformly when the 4-hour period of darkness was either in the morning or afternoon. Those near the outside of the bench were in full bloom several days before those in the middle. This might be due to the angle of incidence of the sun's rays on the cloth. More light was probably admitted through the cloth in the

TABLE II.—EFFECT OF REDUCED LIGHT UPON POMPON VARIETIES

Variety	Treatment	Date Buds Showing	Date First Cut	Days Before Check	Average Number Stems per Plant	Average Stem Length (Inches)	Average Flower Diameter (Inches)	Average Number Flowers per Stem
Bokhara.....	Darkened Not darkened	A-1 S-5	S-9 O-26	47 —	8.6 4.7	14.8 27.9	1.8 1.9	10.5 19.0
Chas. Maynard.....	Darkened Not darkened	A-1 S-5	S-9 O-23	44 —	7.5 3.6	16.4 27.7	1.7 1.7	8.2 13.1
Dorothy Turner.....	Darkened Not darkened	A-7 S-20	O-5 N-23	49 —	6.6 3.9	16.8 31.6	2.0 1.9	9.7 10.9
Golden Menza.....	Darkened Not darkened	A-3 S-15	S-21 N-10	50 —	6.6 3.0	17.5 32.1	3.0 3.0	4.4 7.7
Pink Dot.....	Darkened Not darkened	A-1 S-5	S-9 O-26	47 —	6.9 3.3	13.5 25.7	1.6 1.9	8.8 15.2
Popcorn.....	Darkened Not darkened	A-3 S-15	S-11 N-3	53 —	11.1 4.3	15.5 26.9	1.9 2.1	7.3 18.8
Rodell.....	Darkened Not darkened	A-1 S-5	S-4 O-19	45 —	8.0 6.0	12.6 21.8	1.5 1.4	12.2 16.7
Sunshine.....	Darkened Not darkened	A-5 —	S-28 N-23	56 —	3.7 2.5	22.4 26.0	1.9 2.1	9.0 7.7
White Menza.....	Darkened Not darkened	A-3 S-15	S-21 N-5	45 —	8.1 4.9	19.0 31.3	2.7 3.0	5.0 8.0
Yellow Fellow.....	Darkened Not darkened	A-4 S-19	S-18 N-10	53 —	6.7 4.4	16.6 29.3	2.0 2.1	7.3 11.8

A = August; S = Sept.; O = Oct.; N = Nov.

TABLE III—EFFECT OF DARKENING AT DIFFERENT TIMES OF DAY

Variety	Period of Darkness	Date Buds Showing	Date First Cut	Days Before Check	Average Number Stems per Plant	Average Stem Length (Inches)	Average Flower Diameter (Inches)	Average Number Flowers per Stem
Bokhara...	6 p.m. to 7 a.m.	A-1	S-9	47	8.6	14.8	1.8	10.5
	4 p.m. to night-fall	A-3	S-21	35	7.0	17.6	1.9	7.2
	Nightfall to 9 a.m.	A-18	O-5	21	5.7	19.8	1.8	10.9
	Check	S-5	O-26	—	4.7	27.9	1.9	19.0
	9 a.m. to 1 p.m.	S-15	O-28	-2	5.1	22.9	1.9	11.3

A = Aug.; S = Sept.; O = Oct.;

TABLE IV—EFFECT OF DAY LENGTH UPON BLOOM

Variety	Time Darkened	Number Hours Day Light	Date Buds Showing	Date First Cut	Days Before Check	Average Number Stems per Plant	Average Stem Length (Inches)	Average Number Flowers per Stem	Average Flower diam. (Inches)
Yellow Fellow	6 p.m. to 7 a.m.	11	A-4	S-18	53	6.7	16.6	7.3	2.0
	4 p.m. to 7 a.m.	9	A-11	S-23	48	6.4	16.6	5.9	1.9
	8 p.m. to 7 a.m.	13	A-28	O-30	11	—	24.2	7.9	2.0
	Check	15	S-19	N-10	—	4.4	29.3	11.8	2.1
	6 p.m. to 7 a.m. Tps.	11	S-1	O-15	26	4.6	25.5	14.0	2.0

A = Aug.; S = Sept.

middle than near the edge of the bench. Plants darkened for the same length of time in the middle of the day were weak in growth. In most cases the more effective the treatment in producing early blooms the greater was the number of stems per plant.

TABLE V—EFFECT OF DURATION OF PERIODIC DARKENING TREATMENTS

Variety	Treatment from July 15 Until	Buds Taken	Color Showing	First Cut Dates	Days Before Check	Average Stem Length (Inches)	Average Flower Diameter (Inches)
Gold Lode.	Bloom	A-5	A-18	A-26	48	23.8	3.9
	Aug. 14	A-5	A-20	A-26	48	26	4.4
	Aug. 4	A-5	A-20	A-26	48	26	4.4
	July 24	A-5	A-24	S-8	35	28.4	4.7
	Check	S-11	S-29	O-13		58	4.7

DAY LENGTH AND BLOOM

Varieties Yellow Fellow, Sunshine, Popcorn, Menza, Dorothy Turner were given varying amounts of daylight. The treatment was started July 15 and continued until color was showing in all varieties. The treatment of one plot consisted of covering the top of the frame and the sides down to the terminal buds. The foliage was left exposed to light. All varieties reacted in similar manner, the data being omitted to conserve space.

From Table IV it will be seen that darkening the entire plant from 6 p. m. to 7 a. m., giving the plants 11 hours of daylight, is more effective than longer or shorter periods of daylight. The plot treated from 6 p. m. to 7 a. m. and only the tops darkened produced buds when the plants had grown up under the cloth and were under conditions similar to the completely shaded plot.

NUMBER OF NIGHTS FOR DARKENING

Varieties Gold Lode, Quaker Maid, October Rose, Silver Sheen, Rose Chocard, Chas. Rager, and Friendly Rival were darkened for 10, 20, and 30 successive nights and each night until the bloom was cut. Sixteen plants of each variety were grown in each test. The results with Gold Lode and Chas. Rager follow in Table V.

Table V would indicate that darkening only a few nights in succession may result in bud formation at approximately the same date as when darkening is continued up to the time of bloom. If darkening is not continued until after the buds are all taken, which is from 5 to 7 days after the date given in the table, the time for bud formation to bloom is much greater than when darkening is continued. The tendency is for the plant to return to a vegetative condition. The flowers which form appear very much like those produced on crown buds. Vegetative growth may start from buds on the plant and produce blooms at the normal season of the year. The length of time for darkening was dependent upon the variety. It was best governed

by the development of the bud. Continuing the short days until blooms were cut did not delay the time of bloom. There was more danger of darkening too few nights than darkening too many. Darkening until the blooms were cut slightly reduced the diameter of the

TABLE VI—EFFECT OF BEGINNING TREATMENTS AT VARIOUS TIMES DURING THE SEASON

Variety	Date Treatment Started	Buds Taken	Color Showing	First Cut	Days Before Check	Average Stem Length (Inches)	Average Flower Diameter (Inches)
Silver Sheen.	July 15	A-7	A-21	S-8	45	26.7	4.6
	July 25	A-17	A-26	S-18	35	29.8	4.4
	Aug. 4	A-27	S-5	S-23	30	34.5	4.6
	Aug. 18	S-6	S-22	O-5	18	45.8	4.9
	Check	S-6	O-5	O-23		51.5	5.0

flower. The more effective the treatment the shorter the stem of the flower.

PRODUCING A SUCCESSION OF BLOOM

The treatments of the varieties Snow White, Thanksgiving Pink, Mrs. David F. Roy, Silver Sheen, Quaker Maid, and Chas. Rager were started at various intervals of time during the growing period. The plants were all started and benched at the same time. The results with Silver Sheen appear in Table VI.

When the late varieties were darkened July 15 the reaction to the treatment was not as rapid as that of early varieties. Generally speaking, however, the plants bloomed in approximately the same order in which the treatments were started. The possibility of a succession of bloom of the same variety is evident from this work.

CULTURE UNDER CHEESE CLOTH

The varieties Chas. Maynard, Bokhara, Quaker Maid, and Rose Chocard were planted under a cheese cloth house and given the dark treatment from 6 p. m. to 7 a. m. The plants were in bloom at the same time as those grown in the greenhouse bench and given this treatment. The quality of the blooms of the varieties Bokhara and Chas. Maynard was superior to that of greenhouse grown plants. The standards were severely injured by the presence of moisture in the house.

CONCLUSIONS

Stems of flowers forced into bloom earlier than normal were shorter than those of normal treatment. Buds produced under treatment were terminals. Darkening at 6 p. m. and removing the cloth at 7 a. m. was the most satisfactory of the treatments tried. Darkening from 9 a. m. to 1 p. m. retarded blooming. Darkening the entire plant was more satisfactory than darkening only the upper portion of tops. Darkening until all buds were taken on standard varieties

was most satisfactory. Darkening standard varieties until the blooms were cut reduced the size of blooms of some varieties. Plots in which the treatment was started at intervals of 10 to 14 days bloomed in approximately the same order. Pompons grown continually under tobacco cloth and darkened with stock sateen as those grown in the greenhouse (6 p. m. to 7 a. m.) bloomed at the same time as those grown in the greenhouse and were of superior quality.

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Studies of Photoperiodism of the Chrysanthemum

By G. H. POESCH, *Ohio State University, Columbus, Ohio.*

IN an earlier paper (2) considerable data were presented showing the effect of shortening the length of day on Chrysanthemum, with a very marked effect on its flowering. Previously it was proven that Chrysanthemum was a short-day plant, and it was also observed that a variety grown in the north would flower several days to a week in advance of the same variety several hundred miles further south. Temperature and light appear to be the limiting factors in earlier flowering of the Chrysanthemum.

Allard (1) showed that it flowered about 2 months earlier when grown in a 10-hour day than in the control plot receiving no treatment. Tincker (3) reports that earlier flowering was obtained with this plant but a much weaker growth was noted in the plots under reduced daylight.

The conclusions recorded previously indicated the possibilities of this practice for commercial use. In fact, many growers have already tried the method advocated and successfully brought their plants into earlier flowering. Because of the wide range of varieties and methods of applying the shades, further studies were carried on by the writer at the Ohio State University.

The cultural practices used followed those in the commercial field. Plants were set at a distance of 8 x 8 inches on June 15. These plants were all pinched on June 23. Standards were grown to two stems per plant; disbuds, to five stems; and on pompons all shoots were allowed to mature. The soil was of a compost nature and 10 pounds of superphosphate per 100 square feet were applied before planting.

Plot No. 1: Shades were applied at 6 p. m. and removed at 7 a. m. Nitrogen was applied weekly from time of planting until color of flower appeared. Plot No. 2: Shades were applied at 6 p. m. and removed at 7 a. m. Nitrogen was applied weekly after terminal bud appeared until flower bud showed color. Plot No. 3: Shades were applied at 6 p. m. and removed at 7 a. m. Potash was applied bi-monthly from date of planting until flower bud showed color. Plot No. 4: Shades were applied at 6 p. m. and removed at 7 a. m. No additional treatment. Plot No. 5: Shades were applied at 4 p. m. and removed at 7 a. m. No additional treatment. Plot No. 6: No light treatment.

Nitrogen was applied as ammonium sulphate at the rate of 2 pounds and muriate of potash at the rate of 1 pound per 100 square feet of bench space.

Supports were constructed over the bench by means of wires to support the cloth. Entire shades, covered all sides of the plants as well as the top. Overhead shades covered the top of the plants. In

the case of standards this shade was placed $3\frac{1}{2}$ feet above the soil, while with pompons the shade was so arranged as to be within several inches from the tip of the plant.

Varieties of both standards and pompons were included. Richmond and Snow White, two mid-season standards, and two mid-season pompons, White Wings and Ida, were used in this test.

Series I: Pompons, shade applied 4 weeks after planting, July 16. Series II: Standards, Richmond and Snow White. Shading applied 4 weeks after planting, July 16. Series III: Standards, Richmond and Snow White. Shade applied 6 weeks after planting, July 29. Series IV: This test included 35 varieties of the standard and disbud type. The first portion received shade from July 16 to August 16; the second portion received shade from August 17 to September 9.

Entire white shades did not produce any beneficial results in earliness. Overhead black as well as overhead white shades did not cut down the duration of the daylight sufficiently to hasten maturity. Plots shaded with entire white shades and followed with entire black shades showed a marked advantage in time of flowering over check. Complete shading with black shades was found to be the most satisfactory method.

The difference obtained when entire black shades followed entire white shades may be attributed entirely to the entire black shades. The latter shade was applied August 27, fully 10 weeks after planting. Up to that date entire white shades were applied to those plots designated. The results show that even late reductions of day have some beneficial effect.

In the case of pompons, overhead black shades showed a marked difference over check, but this earliness was only obtained on the plants grown in the center of the bench. The plants on the outer portions of the bench were not affected by the treatment. This shows that daylight was reduced sufficiently on the plants in the center of the bench, but not enough on those grown near the edge.

Duration of light, rather than the intensity of light, governs the reaction of the Chrysanthemum to earlier flowering. Lath covered frames which cut the intensity from 60 to 75 per cent had no beneficial effect upon the time of flowering. Low light intensities weakened the plant. With the use of white cloth the light intensity was very low, yet the time of flowering was not hastened.

Data show that no difference in time of flowering was obtained when nitrogen or potash fertilizers were applied. Stem length and flower diameter varied somewhat in favor of the non-fertilized plots. Microchemical tests for nitrates, starch, and reducing sugars were made September 9, on all plots in Table I. Tests were made at the tip, mid-section, and base of the stem.

Plots 1 and 2 both receiving nitrogen showed very high amounts of nitrates in all tissues of the stem. The largest amount of nitrate was found to be located in the mid-section of the stem. These same plants showed very small traces of starch in the base of the stem.

Reducing sugars were present in very small amounts in the phloem at the mid-section and tip of the stem.

TABLE I—THE EFFECT OF NITROGEN AND POTASH FERTILIZERS ON THE TIME OF FLOWERING, SHADING APPLIED JULY 16, REMOVED AUGUST 17

Treatment	First Appearance of Bud	Date Bud Showed Color	Date of Cutting	Av. Length Stem	Av. Diam. of Flower
<i>Plot I</i> —N weekly from time of planting					
Richmond.....	Aug. 6	Sept. 8	Sept. 29	21	5.3
Snow White.....	Aug. 7	Sept. 27	Oct. 16	21	5.0
<i>Plot II</i> —N weekly when terminal bud appeared.					
Richmond.....	Aug. 6	Sept. 8	Sept. 29	21	5.3
Snow White.....	Aug. 7	Sept. 22	Oct. 16	22	5.0
<i>Plot III</i> —K bi-monthly					
Richmond.....	Aug. 6	Sept. 8	Sept. 29	20	5.5
Snow White.....	Aug. 7	Sept. 22	Oct. 16	24	5
<i>Plot IV</i> —No fertilizer					
Richmond.....	Aug. 6	Sept. 8	Sept. 29	21	5.7
Snow White.....	Aug. 7	Sept. 22	Oct. 16	24	5.0
<i>Plot V</i> —No fertilizer					
Richmond.....	Aug. 6	Sept. 8	Sept. 29	20	5.7
Snow White.....	Aug. 7	Sept. 22	Oct. 16	26	5.0
<i>Plot VI</i> (No shade treatment)—No fertilizer					
Richmond.....	Sept. 11	Oct. 12	Oct. 23	42	6.0
Snow White.....	Sept. 11	Oct. 19	Nov. 4	40	6.0

Plot III, receiving muriate of potash, showed small amounts of starch in the mid-section of the stem, while traces of reducing sugars were present in the tip and mid-section. Nitrates were abundant in all parts of the stem, especially in the xylem and pith. Plots I and II showed the presence of the largest amount of nitrates in all sections of the stem.

Tests on plants in Plot IV (receiving no fertilizer, but shaded from 6 p. m. until 7 a. m.) and Plot V (which received no fertilizer and was shaded from 4 p. m. until 7 a. m.) were identical. No starch was present, but traces of reducing sugars were found in all sections of the stem. Nitrates were abundant in the pith. Nitrates were as abundant in Plots IV and V as in Plot III, which received potassium bi-monthly and was shaded from 6 p. m. to 7 a. m.

Plot VI, unshaded and unfertilized, was higher in starch than the other plots, while the nitrates compared favorably to the amounts found in Plots III, IV, and V. Reducing sugars were present in larger quantities in this plot than in the other plots. The largest amount was found in the mid-section and tip of the stem.

Previous tests showed that *Chrysanthemums* responded to an 11-hour day and produced slightly better flowers than those grown under shorter days. A further study was made upon the 10-hour day as compared with the 11-hour day but no difference could be determined with the varieties worked with. The slight variations recorded were insignificant.

In a variety test, 35 varieties of standards and disbud pompons were arranged in two plots. One plot was shaded July 16 to August 16. The second plot received shade from August 17 to September 9. Entire shade was used. The results indicated that there was a distinct varietal difference. The early bronzes, such as Indianola and Calumet, faded to yellow. The pink varieties, such as October Rose and Rose Marie, faded to lighter shades. The mid-season varieties responded most favorably to the shading method. Late shading produced beneficial results, but not as favorable as earlier shading. By applying the shades at various dates one variety was made to flower over a period of 6 weeks.

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Vegetative Growth and Flower Production of Summer Annuals When Grown Under Cheese Cloth

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

THE production of cut flowers for commercial purposes during the summer is much limited in many sections of New York State because of weather conditions or insects of various types. The majority of cut flowers on the markets are poor in quality. In an effort to improve this situation cloth shades have been used in the experiments here reported.

The Connecticut Valley tobacco growers use "tobacco cloth" for shading their plants to improve the leaf quality. L. R. Jones of Wisconsin has for some time been using muslin for the protection of aster plants from the leaf hopper which, according to Kunkel (2), spreads aster yellows, in order that he might select strains of asters resistant to the wilt fungous. Ball (1) has used the muslin protection with success for the commercial production of asters. The house used for protection of the plants from insects must be closed at the sides as well as the top.

The tobacco cloth used in this work was purchased in 33-foot and 6-foot widths. The greater width was used for the top of the house and the 6-foot width for the sides. For convenience in construction the house was built 32 feet wide and 48 feet long. Ten-foot chestnut posts were set 3 feet in the ground, 16 feet apart at the ends of the house and 24 feet apart along the sides. Provision was made for a door at the middle post on one side. At a distance of 3 feet from the base of the post and on the outside of the enclosure a cedar piece 2 inches x 4 inches x 24 inches was buried parallel to the house to a depth of 18 inches in the ground. No. 10 galvanized wire was fastened to the middle of this piece and run to the chestnut post at a height of 6 feet from the ground and run through a half-inch hole in the post and fastened securely. The same size wire was run entirely around the house at a height of 6 feet and a cross wire was run from each of the posts, at the middle of the house, to the one opposite. All wires were tightened after being run through the half-inch hole in the post. An 8-inch cedar board was placed on edge around the entire house at such distance from the chestnut posts as the brace wires would permit. The 33-foot muslin (tobacco cloth) was sewed to the top wire around the entire edge, and one side of the 6-foot cloth attached in a similar manner. The other side of the 6-foot cloth was then fastened to the base board.

RESULTS WITH ASTERS

The majority of miscellaneous annuals were planted from 2-inch pots to the house, June 3. A plot of the same varieties were planted in a soil area at the south side of the house. Both plots were fertilized

TABLE I.—EFFECT OF CLOTH HOUSES ON *Callistephus chinensis*

Variety	Wilt Resistant (Per cent)		Average Stem Length (inches)		Average Flower Diam. (inches)		Av. No. Flowers per Sq. Ft.		Returns per Sq. Ft. ¹		
	Cloth	Open	Cloth	Open	Cloth	Open	Cloth	Open	Cloth @ 5c.	Cloth @ 2c.	Open @ 2c.
Early Royal Purple (Ball)	33	0	18.9	—	2.8	—	6.9	—	\$.345	\$.138	—
Early Royal Purple (Ball Res.)	93	59	18.5	9.6	2.8	2.1	14.6	2.3	.730	.292	.046
Early Royal Purple (Wis. 40a)	100	63	20.3	—	3.0	—	10.2	—	.510	.204	—
Early Rose (Ball)	83	0	17.3	—	2.5	—	5.5	.5	.275	.110	.010
Giant Branching Shell Pink (Ball)	83	56	22.5	10.2	2.5	2.0	6.2	.7	.310	.124	.014
Giant Branching Shell Pink (Ball Res.)	84	23	19.6	9.2	3.5	2.4	10.6	—	.530	.212	—
Giant Branching Shell Pink (Wis. 65a)	39	38	22.8	—	3.4	—	5.7	—	.285	.114	—
Giant Branching White (Ball)	38	0	25.1	—	3.5	—	6.3	—	.315	.126	—
Giant Branching White (Ball Res.)	90	55	25.7	12.0	3.5	2.5	7.8	1.9	.390	.156	.038
Giant Branching White (Wis. 49)	70	70	23.7	13.1	4.0	3.0	6.5	2.0	.325	.130	.040
Giant Branching Red (Wis. 51b)	30	34	16.3	7.0	3.0	2.4	8.7	2.1	.435	.174	.042
Hearts of France Red (Wis. 1-b)	50	5	17.6	—	3.5	—	9.0	—	.450	.180	—
Commet like Pink (Wis. 12b)	79	63	19.2	—	4.0	—	7.8	—	.390	.156	—
Late White (Ball)	40	15	19.7	—	3.3	—	7.6	—	.380	.152	—
Late Lavender (Ball)	55	26	18.9	8.5	3.0	2.1	8.6	.5	.430	.172	.010
Late Rose (Ball)	80	37	21.0	—	3.2	—	9.6	—	.480	.192	—
Sunshine Mixed (Ball)	47	10	18.1	—	3.7	—	2.0	—	.100	.040	—
Giant Peony Flowered (Stump and Walter)											
Apple Blossom	11	0	26.0	—	3.5	—	1.9	—	.095	.038	—
White	4	4	20.0	—	4.0	—	.3	—	.015	.006	—
Rose	20	0	15.0	—	2.1	—	3.2	—	.160	.064	—
Purple	14	0	16.2	—	2.0	—	2.1	—	.105	.042	—
Average all varieties (21)	54.8	26.5	20.4	9.9	3.2	2.3	6.72	.47	\$.336	\$.154	\$.010

¹22 plants of each variety used, 44 plants of a variety of all others were used.

and cared for in the same manner, excepting it became necessary to stake the plants in the house. The plants were set 9 x 15 inches.

Table I gives the results obtained when various varieties and strains of Asters (*Callistephus chinensis*) were grown under cloth and out of doors.

TABLE II—EFFECT OF CLOTH HOUSE ON MISCELLANEOUS ANNUALS

Variety	Period of Production	Treatment	Av. No. Flowers per Plant	Av. Stem Length (Inches)	Av. Flower Diameter (Inches)
<i>Centaurea cyanus</i>	1931 7/6-7/30	Cloth	33.4	7.8	1.26
		Open	26.4	5.4	.95
<i>Scabiosa atropurpurea</i> ...	8/4-10/4	Cloth	38.1	15.8	2.1
		Open	26.0	11.6	1.8
<i>Trachymene caerulea</i>	8/4-10/4	Cloth	—	16.1	2.0
		Open	—	6.2	1.3
<i>Calendula officinalis</i> Var. Orange.....	7/13-8/3 1st crop 9/5-10/3 2d crop	Cloth	12.9	20.3	2.35
		Open	15.0	15.2	1.90
		Cloth	4.4	16.4	2.70
		Open	6.9	9.9	2.20
		—	17.3	19.3	2.4
Total	—	Open	21.9	13.4	1.9
<i>Calendula officinalis</i> Var. Gold.....	7/13-8/3 1st crop 9/5-10/3 2d crop	Cloth	12.1	19.6	2.36
		Open	13.0	16.3	2.04
		Cloth	4.1	14.9	2.70
		Open	6.3	11.2	2.20
		—	16.2	18.3	2.4
Total	—	Open	19.3	14.5	2.0
<i>Tagetes erecta</i> Var. Lemon.....	7/9-9/25	Cloth	15.0	12.2	2.2
		Open	.8	6.0	1.8
<i>Tagetes erecta</i> Var. Orange.....	7/9-9/25	Cloth	12.7	14.5	2.5
		Open	2.5	9.0	1.8
<i>Zinnia elegans</i>	7/9-9-25	Cloth	17.2	22.2	2.9
		Open	11.5	12.4	2.4
<i>Dahlia variabilis</i> Var. Yellow Gem.....	7/9-9/25	Cloth	66.3	13.8	2.0
		Open	.4	5.	1.5
<i>Dahlia variabilis</i> Var. Nellie Fraser.....	7/9-9/25	Cloth	59.6	10.2	1.5
		Open	3.0	5.0	1.5

The Wisconsin strains are the result of selection work which has been carried on at the Wisconsin Station by L. R. Jones. The seeds for these varieties were secured directly from him. The seeds of other varieties were furnished by George J. Ball, and the varieties

marked Ball Resistant are strains selected by Dr. Jones but grown and selected for resistance by Mr. Ball for one year.

TABLE III—EFFECT OF CLOTH HOUSE ON SPIKE FLOWERED ANNUALS

Variety, Production Time	Treatment	Av. No. Stems per Plant	Av. Stem Length to Basal Flower (Inches)	Av. Flower Spike from Basal Flower to Tip (Inches)	Total Length of Stem and Flower (Inches)
<i>Delphinium ajacis</i> —Blue... 7/13-8/18	Cloth	11.2	10.4	6.9	17.3
	Open	11.3	8.9	6.3	15.2
<i>Delphinium ajacis</i> —Pink... 7/13-8/18	Cloth	12.6	10.7	5.6	16.3
	Open	15.8	9.1	5.4	14.5
<i>Pentstemon gloxinoides</i> 8/30-9/21	Cloth	1.1	13.1	17.5	30.6
	Open	.8	7.5	8.0	15.5
<i>Matthiola incana</i> Bismarck, Lavender	Cloth	1.1	8.3	4.3	12.6
Rose	Open	.5	8.3	4.5	12.8
7/15-9/15	Cloth	1.0	9.2	5.1	14.3
	Open	.3	9.0	5.4	14.4
<i>Antirrhinum majalis</i> Var. Geneva Pink					
1st crop—7/6-7/23.....	Cloth	7.0	9.1	6.2	15.3
	Open	5.3	6.6	4.1	10.7
2d crop—8/20-9/22.....	Cloth	8.3	12.0	5.1	17.1
	Open	3.5	8.9	4.6	13.5
Total	Cloth	15.3	10.7	5.3	16.0
	Open	8.3	7.5	4.3	11.8
Var. Ceylon Court					
1st crop—7/16-7/23.....	Cloth	8.0	9.0	5.1	14.1
	Open	6.0	6.1	3.7	9.8
2d crop—8/20-9/22.....	Cloth	8.8	11.9	4.7	16.6
	Open	3.3	8.5	4.4	13.3
Total	Cloth	16.8	10.8	4.9	25.7
	Open	9.3	7.0	3.9	10.9
Var. Cheviot Maid					
1st crop—7/16-7/23.....	Cloth	8.2	8.4	5.3	13.7
	Open	8.1	6.1	3.7	9.8
2d crop—8/9-9/22	Cloth	7.7	12.6	4.0	16.6
	Open	2.7	7.3	4.4	11.7
Total.....	Cloth	15.9	11.4	4.7	16.1
	Open	10.8	6.0	3.9	9.9

The results show a decided variation in the resistance of varieties to wilt. Those selected for resistance to wilt were in the majority of cases more resistant than those which had not been selected. There was decidedly fewer wilted plants under cloth than in the open.

The average stem length and flower diameter were much greater under the cloth protection. The average production per square foot under the cloth was also much greater than in the open. The returns per square foot of ground area were based on average returns from flowers sent to the Philadelphia and New York markets. The insects which caused considerable damage to the unshaded plants were, the tarnished plant bug (*Lygus pratensis*), the aster blister beetle (*Epi-*

cauta pennsylvanica) and the leaf hopper (*Cicadula sexnotata*). The plants in the enclosures were protected from them.

MISCELLANEOUS ANNUALS

Twenty-two plants of each of the following annuals were planted under cloth and in the open plot. Only three plants of each variety of dahlias were used. The average production per plant, stem length, and flower diameter are also indicated in Table II.

It will be noticed that in all cases the length of stem and diameter of the flower were greatly increased when the plants were grown under the cloth protection. The average production per plant was increased in all cases excepting the Calendula. Here the quality of the flowers was much superior to those produced in the open. Calendulas, Trachymene, and Dahlias were particularly benefited. Zinnias and Tagetes were inclined to be soft-stemmed and the flowers would frequently break off from the stem. The tarnished plant bug stung practically all the buds of Dahlias, Tagetes and Zinnias grown in the open.

Forty-four plants of each variety of annual delphinium, twenty-two plants of *Pentstemon gloxinoides*, sixty plants of each variety of *Matthiola incana*, variety Bismark, and twenty plants of each variety of *Antirrhinum* were planted both under cloth and in the open in the following test. The average production per plant, average stem length to the base of the flower head, the average length of the flower head and the total length of the flower and stem will be noted in Table III.

The delphinium spikes were of superior quality when grown under cloth although the difference in length of spike was very slight. *Pentstemon gloxinoides* flowers remained on the stem much better under cloth than out of doors and the spikes were superior in quality. *Matthiola incana* and *Antirrhinum majalis* were much superior when grown under cloth. The bees were not present under cloth to pollinate the flowers and it was possible to obtain much longer flower spikes.

CONCLUSIONS

Fewer aster plants wilted when grown under cloth. The diameter of the flowers and length of spike, of spike-flowered plants, was greater from the plants grown under cloth. The length of stem of the flowers was increased when the plants were grown under cloth. The cloth house prevented attacks of many insects. The quality of flowers of some varieties was superior to those grown in the open. Some varieties produced soft stems when grown under cloth. The cloth house has commercial possibilities for summer cut flowers.

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The Effect on Gladioli of Heating the Soil with Electricity

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IN California, Florida, and many of the southern states, gladioli corms can be planted outdoors in the fall and flowering spikes produced in early spring. The time from planting to blooming varies with the variety, and to a considerable extent with the age of the corm. Corms that have been freshly dug will not begin to grow for 6 to 12 weeks depending upon the length of the rest period. Corms in storage will usually show bud and root activity when the rest period is over and start growth immediately after planting. Considerable work has been done to devise methods of shortening this rest period. Loomis and Evans (1) state that high soil temperatures as well as storage at high temperatures were very effective.

This paper gives results of the effects of heating the soil on yield and time of flowering of gladioli. Corms were planted 2 inches deep and 4 inches apart in rows spaced 1 foot apart. The varieties used were Prince of Wales and Shaylor. No. 1 corms were used in each case. Fifty-four corms of Prince of Wales and 36 of Shaylor were planted in the heated plot and the same number in the unheated check plot.

The tests were conducted in a coldframe. There was a 1-foot pathway between the heated and check plots. The heating element used was a special soil heating wire. This wire was 43 feet long and consisted of a No. 22 resistance wire wrapped with 2 layers of asphalt saturated cotton and enclosed in a lead sheath $\frac{3}{64}$ of an inch thick. The overall diameter of the cable was approximately $\frac{3}{16}$ of an inch. The temperature in the plot was controlled by a bimetallic thermostat operating a relay switch. All of the heating equipment was operated on a 110-volt circuit.

The heating wire was placed in the soil at a depth of 5 inches midway between the rows of gladioli. This gave an artificial source of heat at approximately 6 inches from the row on each side. The total connected load for the plot, which was 6 feet by 7 feet or 42 square feet, was 507 watts or 12 watts per square foot. The heat added to the soil in one hour of operation was 1750 B.T.U. (436 large calories).

The bimetallic coil operating the thermostat was approximately 10 inches long and was enclosed in a copper tube which was placed vertically in the soil from the surface down. Thus the thermostat was controlled by the temperature in the top 10 inches of soil.

The temperatures in the plots were taken by bulb type recording thermometers. The bulbs were 11 inches long and were placed vertically in the soil from the surface down so that the temperatures recorded were approximately the average of the top 11 inches of soil.

The heat was applied for 96 days (January 14 to April 20), and the total power consumption during that time was 533 kilowatt-hours,

TABLE I—POWER CONSUMPTION AND TEMPERATURES IN HEATED PLOT OF GLADIOLI

Week	Power Cons. Kw-hrs.	Per cent of Time Heaters Were on	Soil Temperature (Degrees F)		
			Maximum	Minimum	Average
January					
14-25.....	100	68	—	—	—
26-1.....	49	58	76	70	73
February					
2-8.....	48	57	75	73	74
9-15.....	29	34	76	74	75
16-22.....	9	12	73	66	69
23-1.....	54	64	79	72	75
March					
2-8.....	38	45	83	74	78
9-15.....	45	53	82	73	77
16-22.....	32	38	82	73	78
23-29.....	41	48	83	75	79
30-6.....	34	40	86	74	80
April					
7-13.....	33	39	86	75	81
14-20.....	21	25	83	73	78
Total days 96.....	533	—	—	—	—
Average.....	—	45	80	73	77

TABLE II—SOIL TEMPERATURES IN UNHEATED PLOT OF GLADIOLI

Week	Soil Temperature (Degrees F)			Minimum Air Temperature (Degrees F)
	Maximum	Minimum	Average	
January.....				
19-26.....	50	47	49	42
26-1.....	55	51	53	45
February.....				
1-8.....	58	54	56	47
8-15.....	60	56	58	48
15-22.....	60	54	57	44
22-1.....	60	55	57	42
March.....				
1-8.....	65	58	61	41
8-15.....	63	58	60	46
15-22.....	66	62	64	50
22-29.....	66	61	63	48
29-6.....	69	64	66	45
April.....				
6-13.....	72	67	70	48
13-20.....	80	70	75	47
Average.....	63	58	60	46

or an average of 5.55 kilowatt-hours per day. The heating element operated an average of 45 per cent of the time.

The average maximum and minimum soil temperatures in the heated plot while the heating mechanism was connected were 80 de-

degrees F. (26.6 degrees C.) and 73 degrees F. (22.8 degrees C.), respectively. The average maximum and minimum soil temperatures during the same period in the check plot were 63 degrees F. (17.2 degrees C.) and 58 degrees F. (14.4 degrees C.), respectively. The average minimum air temperature surrounding the plots was 46 degrees F. (7.8 degrees C.).

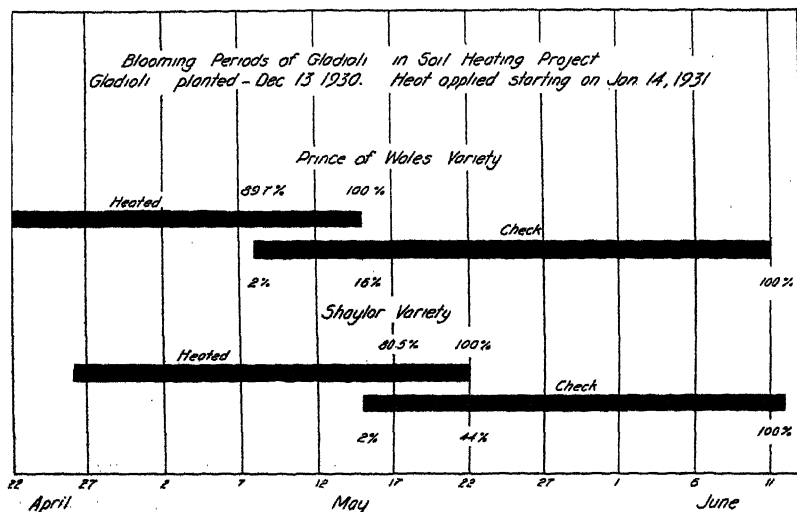


FIG. 1. Blooming period of gladioli in soil heating projects.

The corms used were grown at Davis and were harvested the first week in November. They were stored in trays in a room in which the temperature was not controlled. All corms were planted on December 15, 1930; the first heat was applied January 14, 1931. There was no appreciable root development at the time the heat was applied although a few small root protuberances were found.

On February 8, all the corms in the heated plot had produced considerable leaf growth above the soil while in the check plot the leaves were just beginning to emerge. Growth in the heated plot was constantly in advance of the check plot as shown by Fig. 1. The color of the foliage in the heated plots at this time was a light green, but gradually became normal. The blooming periods are also shown in Fig. 1. In the heated plot the first flower of the Prince of Wales variety was open on April 22. In the check plot this variety did not begin blooming until May 8. By this time 90 per cent of the plants in the heated plot had bloomed. In the heated plot the first flower of the Shaylor variety bloomed somewhat later than the Prince of Wales, the first flower opening on April 26, and in the check plot the first flower opened May 15. By this time 80 per cent of the plants in the heated plot had bloomed.

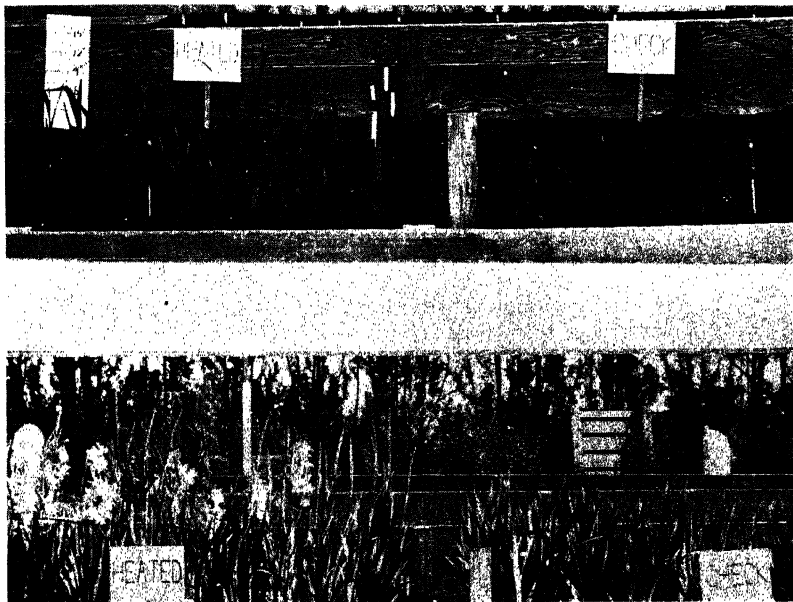


PLATE I.—The upper picture was taken on February 8; the lower on April 28. The heated plot was consistently earlier in growth and flowering.

On May 15 all of the Prince of Wales plants in the heated plot had bloomed; but in the check plot blooming was not over until June 11. Similar results were obtained with the Shaylor variety. There was no appreciable difference in the quality of flowers produced in the heated and check plots.

TABLE III—YIELD OF CORMS AND CORMELS FROM HEATED AND CHECK PLOTS

Variety	Treatment	Number of Corms	Average Weight of Corms (Grams)	Weight of Cormels (Grams)
Prince of Wales.....	Heated	62	43.5	260
	Check	79	27.0	72
Shaylor.....	Heated	41	27.0	232
	Check	34	22.0	202

The corms in the heated and check plots were dug and compared carefully to determine the effects of soil heating. While the number of corms was perhaps too small to place much significance on the results, yet a few facts were consistent throughout. Table III shows that the heated plots produced larger corms and also a higher yield of cormels. This is particularly true of the Prince of Wales variety.

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Forcing Plants With Artificial Light

By G. H. POESCH, *Ohio State University, Columbus, Ohio.*

LIGHT has long been known to be an important factor in influencing vegetative and reproductive development in plants. This response of the plants toward light has been recognized by many workers. Adams (1) reported that with the use of long day plants, the plants exposed the longest to light gave greatest average weight, greatest average height and earliest flowering. This same writer in another paper (2) reported that by using continuous illumination from 700-watt lamps, he found that tulip and hyacinth developed their natural color. Garner and Allard (3) and Tincker (4) have done much work in determining the reaction of various plants to additional illumination.

A series of tests using 75- and 150-watt clear glass lamps were set up to supply the artificial light for cuttings, potted plants, annuals, and perennials. Over 70 different kinds of plants were worked with during the past season. In all cases 4 hours of additional illumination were given the plants. This was applied from 6 to 10 p. m. each day.

The lamps using 12-inch glass reflectors were suspended so that the plants were 18 inches below the light, and arranged to cover from 12 to 15 square feet of bench space. When the lower wattage bulbs were used the space covered was reduced proportionately. The cost of electricity was figured at Columbus, Ohio, rates which amounted to 3 cents per kilowatt-hour.

RESULTS WITH POTTED PLANTS

Potted plants were grown under illumination from 150-watt lamps. *Calceolaria* reacted very favorably to added illumination, a difference of 42 days in earliness being obtained over that of the check plants. Plants were placed under test November 12 and the plants receiving additional illumination flowered February 12. The check plants flowered March 26. The cost of added light was 9 cents per plant.

Iris tingitana, variety Wedgewood, was placed under additional illumination December 13 and flowered March 2. No difference in time of flowering was noted. Those under added light produced 97 per cent bloom; whereas those in the check plots gave 47 per cent, showing a difference of 50 per cent in favor of additional light. The stem length was 3.5 inches longer under additional light.

Cyclamen and primrose both responded to the additional illumination treatment received in the late fall. The difference was recorded in the earliness of flowers and the size of the plant, but the differences secured do not warrant the treatment, from a commercial standpoint.

Cineraria multiflora and *stellata*, receiving 4 hours of additional light, flowered from 8 to 20 days in advance of check plants. Muscari produced one spike per bulb more under light as compared with the

check, but no difference in time of flowering was obtained. The average stem length was 1.5 inches in favor of added light.

No difference was obtained when *Asparagus sprengeri* and *plumosus*, *Achyranthes brilliantissima*, Narcissus, Hyacinth, *Pelargonium hortorum*, *Lilium harrisii*, *erabu*, and *longiflorum giganteum* were placed under additional illumination in February and March. A difference would undoubtedly result in some of these plants if the experiment was carried on during December and January. *Zantedeschia aethiopica* gave no difference in production of flowers where light was added as compared with check plants. Freesias were decidedly retarded under added light. Those grown in normal day-length produced the largest number and longest stemmed flowers.

RESULTS WITH BENCH CROPS

Carnations, White Matchless, were given additional light, using 150-watt bulbs from November 4 to April 9. Four lamps were used to supply the additional light for 150 plants. There was no significant difference in flower diameter or stem length but there were 6.9 flowers per plant in the check group as compared with 8.14 in the light.

The increase in production under the additional light was from March 15 to May 15. After that time the check plot gained rapidly. A slight increase may be expected, but the greatest benefit derived from additional light is earliness. The cost of obtaining the additional 1.24 flowers per plant was 6.4 cents.

RESULTS WITH ANNUALS

Annuals were sown September 25 and benched December 4. Each plot received 4 hours of additional illumination. Ten 150-watt lamps covered 157 square feet of bench space, placed 4 feet apart and 15 inches above the plant and raised from time to time as the plants grew. The results are given in Table I.

Many of the annuals responded to the additional light. The practicability of the use of this additional light commercially depends upon the factor of cost. Under the tests conducted the additional expense for the electric current was 3.4 cents per square foot per 30 day month. The cost is low. Feverfew may be used as an illustration. The additional cost of added light in the case of this crop was 8.3 cents per plant for the entire length of application, and the cost for each individual flowering stem is only .6 of a cent. This slight additional expense is more than balanced by the higher price secured, due to the earliness of the crop so produced, particularly since it is marketed at a time when such flowers are not available under ordinary conditions of culture. Some of the annuals that responded very favorably were: *Centaurea cyanus*, *Centaurea imperialis*, Scabiosa, Didiscus, Schizanthus, Feverfew, Annual Chrysanthemum, and Salpiglossis.

When annuals such as *Leptosyne maritima*, *Centaurea suaveolens*, *Zinnia mexicana*, and *Callistephus hortensis* var. Sunshine, were

TABLE I—EFFECT OF ADDITIONAL ILLUMINATION UPON ANNUALS

Plant Material	Av. No. Flowers per Plant		Av. Stem Length		Date of Flowering		Diff. in Flg (Days)	Cost per Sq. Ft.	Cost per Flower
	Check	Light	Check	Light	Check	Light			
Annual Chrysanthemum.....	20.8	33.0	12.4	11.7	May 9	Apr. 19	20	8.8c.	.26c.
<i>Centaurea cyanus</i>	123.2	76.6	8.3	11.8	Apr. 25	Mar. 17	39	7.2	.009
Scabiosa.....	21.9	45.5	12.0	14.6	June 8	May 6	33	8.8	.19
Calendula.....	10.3	9.7	11.2	11.7	Feb. 17	Feb. 17	—	8.8	.9
Calliposis.....	—	—	—	—	May 12	Mar. 21	52	8.8	.006
Cynoglossum.....	9.1	2.7	13.4	18.4	May 9	Apr. 13	26	8.8	3.1
Annual Larkspur.....	15.0	18.4	23.4	21.2	Apr. 7	Apr. 3	4	8.8	.47
Candytuft.....	9.3	9.2	19.4	16.5	May 18	Apr. 20	28	8.8	.9
Salpiglossis.....	3.8	2.4	35.6	30.0	May 12	Apr. 20	22	8.8	3.6
<i>Centaurea imberialis</i>	16.2	60.4	14.1	12.7	Apr. 23	Apr. 7	16	8.8	.14
<i>Tagetes erecta</i>	2.5	3.5	7.4	12.2	Apr. 16	Apr. 16	—	8.8	2.5
Snaptdragon, Cheviot Maid.....	5.6	3.6	22.9	20.3	Mar. 21	Mar. 6	15	6.5	1.8
Schizanthus.....	18.0	14.1	19.5	18.5	Feb. 28	Jan. 28	31	3.4	.24
Didiscus.....	30.6	27.9	9.1	10.1	May 9	Apr. 14	25	8.8	.31
Peverfew.....	9.7	13.2	28.8	12.1	May 28	Apr. 1	57	8.3	.62

TABLE II—EFFECT OF ADDITIONAL ILLUMINATION UPON PERENNIALS

Plant	Av. No. Flowers per Plant		Av. Stem Length		Date of Flowering		Diff. in Flowering (Days)	Cost per Sq. Ft.	Cost per Flower
	Check	Light	Check	Light	Check	Light			
Coreopsis.....	102.5	146.4	13.0	13.0	May 21	Apr. 20	31	7.0c.	.05c.
Gaillardia.....	8.4	41.2	12.1	13.9	May 11	Apr. 2	39	7.0	.16
Shasta Daisy.....	7.4	10.4	15.8	15.5	Apr. 13	Mar. 17	27	5.3	.50
Pansy.....	28.7	44.2	—	—	Feb. 20	Feb. 20	—	7.0	.15
Delphinium.....	2.2	2.5	22.8	24.1	Apr. 23	Apr. 14	9	7.0	2.8
Achillea.....	24.1	15.0	19.1	21.9	May 9	Apr. 7	29	7.0	.46

planted September 18 in the bench plus 4 hours of additional illumination, they flowered November 15.

RESULTS WITH PERENNIALS

Another test to determine the value of additional illumination was tried on a variety of perennials. The plants were removed from the field and placed in a greenhouse at 50 degrees F. on January 6. Eighteen 75-watt bulbs were the source of light, which covered 200 square feet. The results are given in Table II.

TABLE III—EFFECT OF ADDITIONAL ILLUMINATION UPON GLADIOLI

Crop	Check			Light		
	1st Planting	2nd Planting	3rd Planting	1st Planting	2nd Planting	3rd Planting
Halley.....	10	30	90	20	10	75
Coleman.....	55	90	35	95	95	75
Sunbeam.....	115	115	75	105	115	110
Myrtle.....	0	60	50	70	25	50
Pendleton.....	75	95	70	70	80	40
Virginia.....	5	25	55	75	120	85
Peachblossom.....	—	205	—	—	180	—
Los Angeles.....	0	38	—	77	60	—

It can be seen readily that Coreopsis grown as the check flowered only several days earlier than those grown out of doors, while those under added light flowered 31 days in advance of the check. The cost per flower was only .05 cents each. Pansies flowered more freely under light, producing 36 per cent more flowers. The quality and length of stem was also superior under additional illumination.

Coreopsis, Gaillardia, Pansy, and Shasta Daisy were the best perennials for this purpose. Undoubtedly many other perennials might respond in a similar way. Two-year-old, field-grown plants should be used for forcing.

The commercial value of small wattage electric lights for Gladioli is questionable. The corms were harvested early in the summer and were in good planting condition. Three separate plantings were made, October 25, November 15, and December 13. The 150-watt bulbs were used and applied when the spikes reached a height of 4 inches.

The percentage figures for the total number of plants which flowered is shown in Table III.

The cost of using electric lights for Gladioli is too high for commercial purposes. Only three of the eight varieties responded to the addition of light. However, in the case of Los Angeles, light was of value as it gave 77 per cent as compared with 0 under check. Coleman and Virginia responded to additional illumination. In general, however, the slight increase in production is not sufficient to equal the cost of electricity.

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Flower Bud Differentiation in the *Gladiolus*¹

By JOHN V. WATKINS, *University of Florida, Gainesville, Fla.*

IN 1930 the author undertook to establish, through a histological study of the growing points of flowering size corms, the time in the life cycle of the gladiolus that flower buds are formed.

Jones (6) reports that in Massachusetts flower primordia are differentiated, in the case of a flowering size corm, a few weeks after planting. Abbott (1) in his work on the Tung oil tree, has found that in Alachua County, Florida, differentiation may occur any time between May 10 and October 1. The vigor of the trees and the soil moisture had a marked influence upon the time of differentiation. Bradford (2) reports a very wide range in the time of fruit and bud formation in the apple, as do Goff (4) and Drinkard (3) in the apple and other fruits. Isbell (5) and Shuhart (7) show that flower buds in the pecan are formed in the spring after growth starts.

SOURCE OF MATERIAL AND TECHNIC

The buds used in the histological work were collected from flowering size corms from the bulb lockers or gardens of the Horticultural Department of the University of Florida.

Buds were collected as follows: (1) at digging time; (2) at one month intervals during the rest period; (3) immediately before cold storage; (4) immediately after cold storage; (5) at planting time, and (6) at weekly intervals from planting time to digging time.

Simple histological technic was used in the work. After the buds were collected they were stored in 70 per cent alcohol until needed. They were dehydrated in alcohol, cleared in xylene, and embedded in paraffin. A rotary microtome was used to cut the sections, 10 microns in thickness. Delafield's haematoxylin proved satisfactory as a stain.

CONCLUSIONS

The histological studies of the gladiolus buds reveal that flower spikes are formed after growth has started during the current growing season. There is no evidence that differentiation takes place either during the ripening process following anthesis or during the storage period following digging. After the rest period is complete and when growth starts, definite activity at the growing point can be seen, which the series of slides showed to be pre-differentiation stages. This pre-differentiation condition is characterized by a substantial broadening of the growing point, together with a lobing that is, in

¹Part of a thesis presented to the Graduate Council of the University of Florida, in partial fulfilment of the requirements for the degree of Master of Science in Agriculture.

all probability, the first indication of the formation of the lowest florets on the spike, which are the first to form.

In view of the fact that gladiolus corms may be planted at any month of the year in Florida, it cannot be said that the flower buds are formed at any definite season as it can with the tree crops. Because some varieties require much less time to bloom than do others, and because high soil and air temperatures seem to diminish the time to bloom in all varieties, it cannot be said that a definite number of days elapses between planting and flower formation.

The author feels that it is safe to say that flower bud differentiation in the gladiolus may occur shortly after growth has started during the current growing season.

The amount of food stored in the corm, the length of the rest period previous to planting, the food and water supply, and the air and soil temperatures in all probability have a definite bearing upon the time of flower spike formation in the gladiolus.

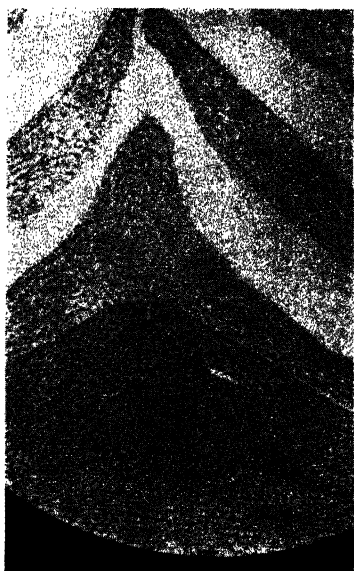
In one case, an inflorescence primordium was found in a bud of the variety Baron Jules Hulot after it had lain in the bulb locker for 6 months. This corm sprouted in storage, indicating that the rest period had passed, but it had not been planted when the bud was collected for histological examination. This is the only case in the work that a flower spike was found before the corm had been planted.

It was with this case in mind that the author attempted to determine whether representative corms that were ready to grow, if given a constant water supply but no nutrients, would differentiate flower spikes.

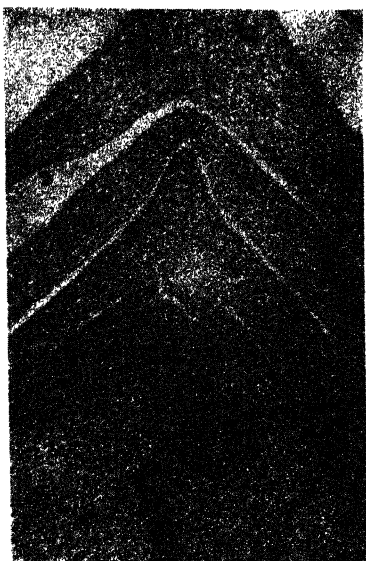
On March 15, 1931, six well-cured, flowering-size corms of the variety Mrs. Francis King were planted in a shallow pan of sphagnum moss so that the tops of the corms were just under the surface. The pan was placed in a sunny greenhouse bench and watered freely every day. Growth of the roots and leaves started at an early date and continued in a satisfactory manner, although the plants were, as one would anticipate, much weaker than plants grown under favorable nutrient conditions. On April 26, 1931, when the leaves aver-

EXPLANATION OF PLATE I.

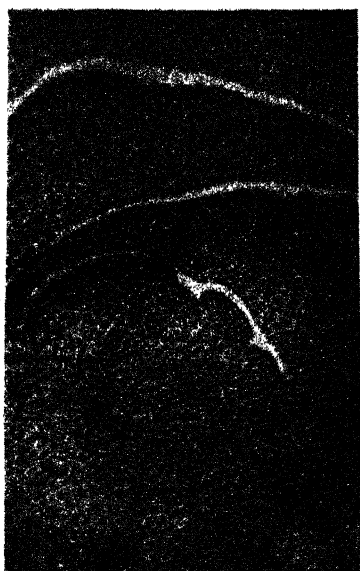
- A. Typical condition of the growing point within a gladiolus but at the time of anthesis. The growing point is even in outline, unlobed, and comparatively small in size. $\times 90$.
- B. An undifferentiated stage. Note a slight elongation and the first indication of lobing on either side of the growing point. This is typical of a dormant corm after it has been dug and stored for its period of rest. $\times 90$.
- C. Situation after a corm has had several months rest, but before active growth has been initiated. There is very little difference in the physical aspect of B as compared with C, although the latter might be considered slightly further advanced. $\times 90$.
- D. A growing point after active growth has commenced. There is substantial increase in size, and lobing is quite pronounced at this stage. There is no definite indication of the formation of a flower spike, but it is interpreted as a typical pre-differentiation condition. $\times 95$.



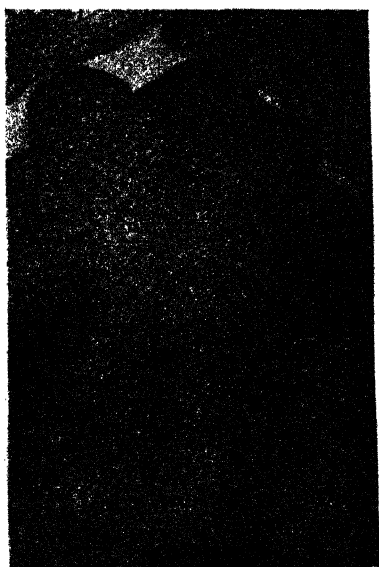
A



B

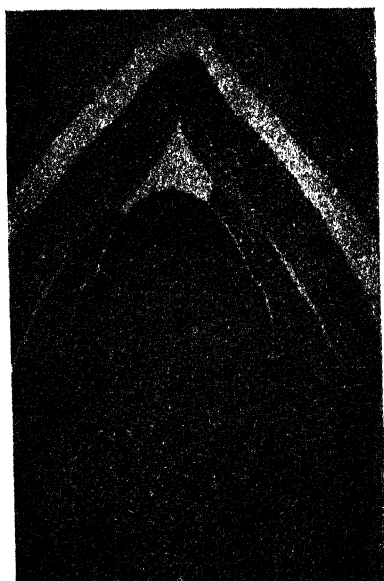


C



D

PLATE I.



A



B



C



D

aged about 18 inches in height, dissection failed to reveal flower spikes. Immediately the experiment was repeated, using the same type of corms of the varieties Mrs. Francis King and Niagara. Dissection under a binocular in June, 1931, revealed immature flower spikes within the leaves. It is evident that these flowering-size corms contained sufficient food within themselves to support vegetative growth as well as flower spike formation.

Souvenir, a primulinus hybrid variety that has a comparatively short interval from planting to blooming, showed well formed inflorescence primordia 23 days after growth had started. In all of the other samples used in the work, it was found that 30 days or more were required to produce a well defined primordial flower spike.

The sections selected from some 200 slides were considered typical of different stages in the development of the inflorescence of the gladiolus and are herewith presented in Plates I and II in series to facilitate an understanding of this development.

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EXPLANATION OF PLATE II.

- A. Median section through a bud after the rest period has been completed and growth has been under way for some time. There is a definite elongation of the primordial flower spike, while the lobes at its base are the first indications of flowers.
- B. A subsequent phase in the development of the primordial inflorescence. Note the newly formed flowers of the gladiolus spike. Differentiation has definitely occurred at this stage. $\times 100$.
- C. Typical unexpanded inflorescence after a corm has produced its typical number of leaves and is growing well. $\times 40$.
- D. A typical gladiolus flower spike of later development. At this stage the spike can be found easily by dissection, and is visible to the naked eye. $\times 40$.

Factors Influencing the Flower Color of Hydrangeas¹

By RAYMOND C. ALLEN, *Cornell University, Ithaca, N. Y.*

THE fact has long been known that varieties of *Hydrangea macrophylla* DC. which normally produce pink flowers may under certain conditions produce blue ones. This change in color was early attributed to some property of the soil, and much investigation has been carried on to determine what factor or factors are responsible for the variation.

Sprengel (9) stated in 1817 that iron salts mixed with the soil in which hydrangeas are growing changes the red color of the flowers to violet or blue. Schübler (8) in 1821 analyzed a soil from the vicinity of Frankfurt which had the capacity to a marked degree to induce blue flowers. Since the analyses showed no greater content of iron than ordinary soil, he concluded that its effectiveness was due to its greater carbon and humus content. According to Schübler, these two substances absorb the oxygen in the soil and under these conditions little oxygen is supplied through the roots resulting in a certain deoxidation which changes the pink color to blue. He further stated that other things such as iron which would become oxidized in the soil could bring about the same effect. In 1846 Donald (4) treated plants with phosphate of iron, sulphate of iron, alum, caustic potash, phosphate of magnesia, and carbonate of potash. Only one plant was used in each treatment. However, the plant that was treated with alum was the only one to produce blue flowers.

Koch (6) as reviewed by Molisch (7) doubts that iron influences the production of blue flowers to any extent. In contrast to this view, Jäger (5) as reviewed by Molisch (7) believes that iron and even alum quite definitely produce the blue coloring. Molisch (7) in 1897 tested several natural soils obtained from various parts of Europe and also many substances reported to be effective in bringing about blue coloration. He found that alum, aluminum sulphate, and ferrous sulphate were able to produce the change in color. He also found that the soils in which hydrangeas produced blue flowers were acid, and concluded that their effectiveness was due to the greater solubility of aluminum and iron in an acid medium. According to Molisch (7), if the plant is supplied with iron in excess of its physiological needs, small amounts of the inorganic iron reach the flower and react with the red anthocyanin to form a blue complex. In 1908 Vouk (10) showed that potassium alum was more effective than aluminum sulphate in producing the blue color.

Atkins (1) in 1923 determined the hydrogen ion concentration of pink and of blue flowers, and since he found no distinguishable difference, concluded that the various colors of hydrangea flowers

¹Joint contribution from the Boyce Thompson Institute for Plant Research, Yonkers, New York, and Department of Floriculture and Ornamental Horticulture, Cornell University, Ithaca, New York.

were not due to the natural pigment acting as an indicator. He analyzed pink and blue flowers for their iron content and found that the pink ones contained only six-tenths as much iron as the blue ones. He stated that the blue coloring brought about by the addition of alum and aluminum sulphate to the soil is due to the increased acidity and consequent liberation of iron. He further stated, however, that the aluminum as well as the iron may form a blue complex with the anthocyanin which is pink in the absence of excess of these salts. Connors (2, 3) in 1923 stated that in general where the pH value of the soil is 6.4 or higher, the flowers are pink; below pH 6.0, they are blue; and between pH 6.0 and pH 6.4, they are of intermediate hues. He pointed out that liming the soil is an effective way to maintain the pink color. He deduced from his studies with lime and other materials that "apparently neither iron nor alum will cause blue color in flowers of the hydrangea, but the acidity brought about because of the presence of iron and alum will tend to produce blue color."

Since many diverse statements have been made concerning the cause of this change in the color of hydrangeas, further investigation of the problem seemed pertinent. It is to be understood that this paper does not represent a completed project, but merely gives the progress to date. Many experiments are under way, and the problem is to be continued and extended to include all aspects of the subject.

EFFECT OF LIGHT

In order to determine whether light was necessary for the formation of color in hydrangea flowers, light-proof caps were constructed on wire frames and placed over buds about 1 inch in diameter before any color appeared. The flowers were allowed to develop and when they reached full growth they were inspected. In contrast to the checks which were pink, the sepals of the covered flowers were found to be pure white.

EFFECT OF INORGANIC CHEMICAL COMPOUNDS

In an endeavor to determine what substance or substances are responsible for the change in color from pink to blue, solutions of several chemical compounds were sprayed onto flowers in different stages of development. It was found that wherever a dilute solution of aluminum sulphate was sprayed onto mature pink flowers, definite blue areas developed on the sepals. As a rule the blue areas were more or less restricted to the outer edge of the sepals. This is probably explained by the fact that the solution did not wet the sepal evenly but flowed to the edge and remained long enough for some to get into the pigment-containing tissue and effect a change in color. No such results were obtained when the flowers were sprayed with a dilute solution of sulphuric acid, ferrous sulphate, ferric chloride, or salts of certain other metals as copper, magnesium, and potassium.

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When buds were sprayed with aluminum sulphate before any color showed, the blue developed as the color began to appear. If buds which were to produce pink flowers were sprayed several times at intervals of a day or two apart, it was possible to obtain full grown flowers of fairly even blue color. Spraying mauve colored flowers with aluminum sulphate produced areas of clear blue around the edges of the sepals.

It was thought that a more striking effect might be obtained by injecting substances directly into the stem. This was done in two ways, namely, with hypodermic needles connected by rubber tubing to an elevated reservoir, and by making an upward diagonal cut forming a tongue about $2\frac{1}{2}$ inches long which was placed in a vial filled with solution. The hypodermic needle method was not as effective as the method in which a cut was made in the stem. The needles frequently became clogged and were not reliable in ejecting a constant flow of solution into the tissue. Making a cut in the stem and permitting the plant to take up the solution from a vial proved to be the most satisfactory method of getting materials into the plant.

Aluminum sulphate, ferrous sulphate, ferric chloride, and sulphuric acid in dilute solutions were injected into flower stems of plants which normally produced pink flowers. It was observed that whenever aluminum sulphate solution was used, intense blue coloration appeared in portions of pink flowers. None of the other solutions tried gave this result. If aluminum sulphate solution was injected about 6 inches below the flower head, only about half of the flower turned blue. The blue portion was always directly correlated with the side of the stem in which the cut was made. It was possible to obtain umbels completely blue by making a fairly deep cut near the base of the stem.

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The Effect of Steaming the Soil on Yields of Carnations

By S. W. DECKER, *University of Illinois, Urbana, Ill.*

IT has been recognized for a long time that old carnation soils do not produce as well as new soils. Florists have found it profitable under ordinary conditions to renew the soil yearly. Workers at various experiment stations have been attempting to find a way of restoring the productiveness of used greenhouse soils.

Weinard and Hall (1) state: "It is evident under ordinary conditions that carnation soils need to be changed each season if the highest yields are to be maintained. This has been shown by experiments extending over a number of years." Their results (2) indicate that a reduction in yields of 10 to 20 per cent is to be expected from soils producing carnations for the second consecutive year. Soils producing carnations for 3 or more consecutive years gave yields comparable to 2-year old soil. Wiggin (3) and Conners (4), also report lower yields from old carnation soils. Wiggin (3) states: "At the Ohio Station it has been found that the decrease is more than equal to the cost of changing the soil."

In the studies here reported, all tests were run in the same house and under as uniform conditions as possible, except for the treatments. The old soils were allowed to lie idle from the latter part of June until the latter part of July, and the soil became very dry. The old soils were pulverized finely before steaming. The soil was treated for 2 hours by the inverted pan method, using steam at 5 pounds pressure. The soil in all parts of the bench reached a temperature of at least 195 degrees F. The steamed new soil was treated in a like manner shortly after being placed in the bench. After steaming, the fertilizers (organic and inorganic) were added, worked into the soil and the area watered before the plants were benched.

The check plots consisted of new soil secured by turning under blue-grass sod and adding to it well rotted manure at the rate of 40 tons to the acre. To this soil, after benching, were added 10 pounds of superphosphate and 5 pounds of blood to 100 square feet of bench. After the plants were benched, they were supplied with liquid fertilizers which carried mainly nitrogen. New soil, steamed, gave an average increase of 11 per cent over the checks. Second-year soil steamed and fertilized with inorganic fertilizers gave a yield on an average of 10 per cent more than the checks. Second-year soil, steamed and fertilized with well rotted manure gave a yield slightly below that of the checks, but considerably above that of the unsteamed second-year soil. The yield secured from Harvester in untreated second-year soil was unusually high. The yields from Early Rose and Spectrum were more in accord with previous findings. The yields for the three varieties on 2-year soil were about 16 per cent lower than that of the checks and approximated previous results.

In 1930-31 the flower production from new and second-year steamed soils was equal to or better than that of the checks. The second-year unsteamed soil had no organic matter added in 1930-31. The results showed a slight decrease as compared with the checks.

TABLE I—FLOWER PRODUCTION OF CARNATIONS IN STEAMED AND UNSTEAMED SOILS, 1930-1931

Treatment	No. Plants	No. Flowers	Stem Length (Inches)	Flower Diameter (Inches)
Variety Harvester				
New soil check.....	44	20.4±.54	14.4	2.79
2-year soil.....	43	18.8±.30	15.4	2.65
New soil steamed.....	127	21.3±.34	15.7	2.76
2-year soil steamed.....	132	20.2±.26	15.3	2.73
Variety Early Rose				
New soil check.....	35	20.4±.48	14.2	2.66
2-year soil.....	30	22.1±.62	12.2	2.46
New soil steamed.....	104	24.0±.38	14.8	2.57
2-year soil steamed.....	103	23.7±.34	14.1	2.61
Variety Spectrum				
New soil check.....	44	19.2±.39	18.0	2.89
2-year soil.....	45	18.8±.36	17.4	2.92
New soil steamed.....	135	20.1±.28	18.2	2.87
2-year soil steamed.....	134	21.1±.27	17.9	2.81

The treatment most often given old greenhouse soils includes the liberal use of humus, usually applied in the form of well rotted manure. In the light of the limited data in Table I it seems likely that this practice may be wrong. If so, this explains the reduction in yields noted where rotted manure was used.

Wiggin (2) states: "Although the plants in sterilized soil will not produce as many, or as long stemmed flowers as in new soil, still a good crop is possible if they are properly handled." In the present studies the stem lengths on steamed soils were equal to those on new soils (Table I). While the average flower diameter on steamed soils was slightly below that on new soil, the difference was not significant.

Smith (3) remarked that one of the effects of steaming a soil is the increasing of the concentration of the soil solution, probably by making more plant nutrients available. From this carnations in steamed soil might be expected to give a heavy production during the fore part of the season only to fall off rapidly later. In practice, the curve of flower production was found to vary with different varieties under the same treatment. Harvester, for example, gave a nearly uniform monthly production from October through March and then increased with the warm spring days. Spectrum showed a low monthly production during the fall, with a nearly uniform monthly production from January through May. Early Rose gave a more or less uniform production throughout the entire season. The seasonal

curve of flower production is illustrated in Fig. 1. This shows that in general the trend of monthly flower production was not altered by steaming the soil.

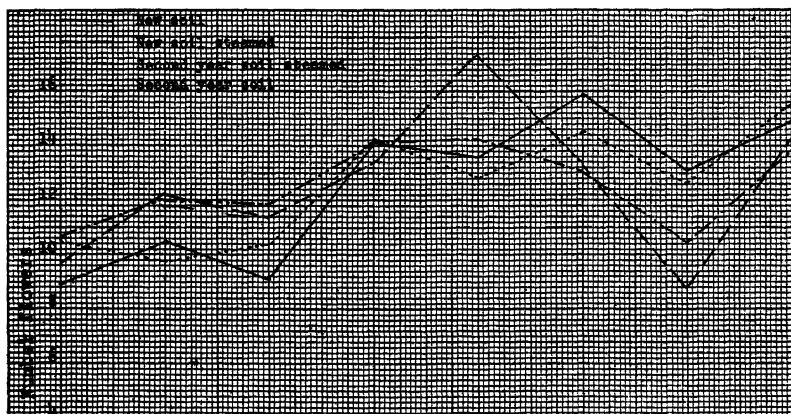


FIG. 1. Monthly Yields from Carnations in Steamed and in Unsteamed Soils.

Some have suggested steaming carnation soil for the prevention of stem rot. It is evident, however, that the losses due to transplanting and disease are influenced greatly by weather conditions. The average losses in 1929-30 were 12 per cent and 2.7 per cent in 1930-31. The losses were practically uniform in all plots regardless of soil treatment, indicating that steaming does not insure against loss.

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The Growth of Several Floricultural Crops on Limed and Acidified Soils

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UNTIL recently there has been very little data available on the responses of floricultural crops to differences in soil reaction. At the same time the interest of growers has been stimulated by references to work with other crops. In order to determine the results to be expected in soils varying in reaction within the range ordinarily found in the greenhouse, several common crops were grown in a bench of limed soil and compared with similar varieties grown in acidified soil.

Two center benches in a 50-foot house were filled in July with a loam compost. The field soil had a pH value of 5.5. Superphosphate and dried blood were added, 10 pounds and 5 pounds respectively, to 100 square feet of bench. At the same time, ground limestone was worked into the soil of one bench, at the rate of 10 pounds to 100 square feet of bench, and sulfur was stirred into the soil in the opposite bench at the rate of 2 pounds to 100 square feet of bench. On August 15, about half a pound of lime was used in solution per 100 square feet of bench. On December 18, the lime plots received 5 pounds of ground limestone, and the acid plots half a pound of sulfur per 100 square feet of bench. During the growing season the reaction of the limed plots was pH 7.0 to 7.5, and that of the acidified plots were pH 5.5 to 5.0. The reaction was measured colorimetrically.

Chrysanthemums, snapdragons, carnations, calendulas and forget-me-nots were grown on the plots described. Freesias and coleus were grown under similar conditions.

Chrysanthemums. Five plants each of ten varieties of chrysanthemums were planted on each bench in July. Five of the varieties were grown five stems to a plant, and the remainder were not disbudded. At the time of cutting, November 8, no consistent differences were found in the growth of the different varieties. The average height of the plants on each bench was about 20 inches.

Snapdragons. Six to eighteen plants each of five varieties of snapdragons were grown, 66 plants in each soil series, following the chrysanthemums. An average of 6.7 spikes per plant were cut on the limed plot, and 6.3 spikes per plant on the acid plot. There were no striking or consistent differences in growth or flowering in the different varieties.

Carnations. One hundred carnation plants were set in each bench. There were 5 plants each of 15 varieties, 10 plants of Harvester and 15 of Spectrum. A record was kept of the flowers cut from the middle of October through April. There were no consistent differences in the number of flowers produced by the different varieties

on the limed as compared with the acid soil. The average cut per plant on the limed soil was 14.7 flowers, and on the acid soil, 14.3 flowers. The stems appeared to be slightly stronger on the limed soil.

Calendulas. Thirty-two plants of Ball's Orange and Ball's Gold were grown on each soil series. From December 5 through March, an average of 10.1 flowers were cut from the plants on the limed plot, and 9.3 flowers from the plants on the acid soil. The flowers were of equally good quality on the two plots.

Forget-me-nots. Eight plants of *Myosotis*, var. Blue Bird, were planted on each plot. The plants bloomed well on both plots, but those on the acid soil began to bloom about 10 days earlier than those on the limed soil.

Freesias. Six feet of each bench were planted with freesias. The soils in this instance were 2 years old, with reactions of pH 8.0 and pH 5.0 respectively. The freesias grew and flowered equally well on the two plots, producing blooms of good commercial quality.

Coleus. In a previous experiment, 12 coleus plants of 4 varieties were grown without pinching in soils testing about pH 7.0 and pH 4.0. When measured on June 30, those on the neutral soil averaged 17 inches in height, and those on the acid soil, 16 inches. The average green weight of the plants on the neutral soil was 173 grams, and of the plants on the acid soil, 157 grams.

The results obtained in these trials indicate that the common flower crops will grow and produce the usual number of commercial blooms within a range of soil reaction of pH 7.5 to pH 5.0. Most greenhouse soils vary within these limits. These results are in general agreement with those obtained by Wiggin and Gourley (1). They found that soil reactions between pH 8.0 and 5.0 had little or no effect on chrysanthemums and carnations. Snapdragons and calendulas seemed somewhat more sensitive, slight differences being reported in favor of reactions near the neutral point. Carnations gave slightly stiffer stems where lime was used. Coleus was reported to do best on slightly acid soil.

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Summer Flowering Phloxes

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THERE are two general classes of summer flowering phloxes, the early or *Phlox suffruticosa* types and the late or *P. decussata* types.

It is difficult to cite with certainty the first horticultural record of phloxes. *Phlox paniculata* was of sufficient importance during the early colonial days to be given the name of Sawpit flower. The name *Lychnidea* was used by Plukenet (19) in 1700 and remained the common name for some time after Linnaeus applied the name *Phlox* to the genus.

Miller's first record of phlox was in the 1735 edition of his "Garden and Botanical Directory" (16). *Lychnidea* was differentiated from *Lychnis* and two species described. Miller gave directions for cultivating phlox in borders and in pots, and stated that the plants did not produce seed in England. The flowers were cut for basins or flower pots to adorn chimney pieces and halls.

The commercial importation of phlox took place largely through Peter Collinson, who received regular shipments of American plants from John Bartram (6) and from Dr. Witt. Collinson also supplied botanists with specimens. His garden notes were used by Dillwyn (8) as the basis for "Hortus Collinsonianus."

During the latter part of the eighteenth century John Fraser of Sloane Square, England, made several expeditions to America and introduced *P. suffruticosa* and a number of the spring flowering species. Following is a summary of the early period of importation of phlox species to Europe (1, 5, 8, 16, 24).

Species	Date of Importation	Cultivated by	Common Name
<i>P. carolina</i>	before 1728	Cowell	
<i>P. glaberrima</i>	1731	Miller	smooth leafed phlox
<i>P. paniculata</i>	1732	Sherard	panicled phlox
<i>P. maculata</i>	1740	Collinson	spotted stalked phlox
<i>P. divaricata</i>	1740	Collinson	early flowering blue phlox
<i>P. scabra</i>	1759	Miller	hairy leafed phlox
<i>P. ovata</i>	1759	Miller	oval leafed phlox
<i>P. undulata</i>	1759	Miller	waved leaf phlox
<i>P. suaveolens</i>	1766	Collinson	whiteflowered phlox
<i>P. amoena</i>	1786	Fraser	
<i>P. setacea</i>	1786	Fraser	fine leafed phlox
<i>P. subulata</i>	1786	Fraser	awl leafed phlox
<i>P. prostrata</i>	1792	Banks	trailing phlox
<i>P. stolonifera</i>	1800	Fraser	creeping phlox

<i>P. pyramidalis</i>	1800	Lee & Kennedy	pyramidal phlox
<i>P. pilosa</i>	1806	Fraser	
<i>P. acuminata</i>	1812	Lyon	cross leafed phlox
			<i>P. decussata</i>
<i>P. macrophylla</i>	1829	Lemon	see <i>P. acuminata</i>

The earliest hybrids appear to have occurred in nature for Bartram (6) described one: "I have another wild one speckled and striped on a white ground and which has a red eye in the middle, the only one I have ever seen."

Collinson also had a form of *P. paniculata*. Sweet described a variety of *P. suaveolens* called *carnea*, grown by Fraser in 1827, and claimed by Nuttall to be native to America. Dickson (7) catalogued (1827) a form of *P. suaveolens* with variegated leaves.

The first hybrids raised in Europe were *P. paniculata*. The varieties, *P. Shephardii* and *P. Wheelerii*, were both grown as early as 1824 (13, 14, 18) and were doubtless introduced by S. Shephard of Bedford (5, 20) and G. Wheeler of Warminster (5, 20,) respectively. The latter had a large collection of phlox and introduced the varieties *P. Wheelerii elegans* and *P. Wheelerii latifolia* in 1837.

Sweet (22) considered *P. reflexa* to be a hybrid between *P. suffruticosa* x *P. pyramidalis*, (Wheeler, 1823). *P. Coldryana*, raised before 1835 by Coldry (15) of the Bristol nurseries, was a seedling of *P. cordata* (*P. paniculata*); it was widely distributed in Europe and also in America. The hybrid *P. cordata omniflora* was also of British origin and very hardy.

In 1838 Rodigas of St. Trond, Belgium, raised the first really striped phlox from a cross of *P. suaveolens* x *P. Carolina* ? and named it in honor of his associate L. Van Houtte, who, in 1840 purchased the variety for 1,200 francs (11). This purchase stimulated the naming of phlox seedlings and encouraged many growers to turn their attention to this flower. In spite of this sudden burst of enthusiasm the variety did not always receive the highest of commendation. A writer in Berlin states that Van Houtteii was not superior to, or more popular than, the variety Princess Marianna (Van Gavers 1838). In America, Carter's Frelinghysen (1844) and Breckii (Breck 1837) were considered of equal merit, but enjoyed a briefer popularity, for the European varieties soon outnumbered the American.

Rodigas continued to introduce phloxes and was described by Hovey (10) as the greatest of all phlox breeders, and as raising 30,000 seedlings. There is definite record of over 70 named varieties of his raising; the most important of these were Van Houtteii, Rodigasii, and Leopoldiana. This last is recorded as the first cross between *P. drummundi* and the perennial type, in this case the variety Van Houtteii.

The French were particularly interested in *P. pyramidalis* x *P. decussata* hybrids. The varieties Charles (Péle 1844) and Comtesse

de Belleval (Mezard 1850) are important. Lierval had some 10,000 seedlings of *P. decussata* by 1848 and in 1860 was raising over 100,000 seedlings each year. It was not till 1850 that his varieties were considered superior to those of Fontaine.

By the middle of the century it was evident that, in spite of the size, beauty and continuity of the bloom, the inherent lack of vigor and hardiness of the suffruticosa types made them unsuitable for general culture. Most of the varieties grew poorly on sandy soil and the literature of the time (2, 4, 11,) contains many suggestions on the proper preparation of the soil for phloxes.

Lierval (12) became interested in the *P. decussata* hybrids in 1839 and devoted his efforts to their improvement through artificial pollination. In 1866 he published "Culture Pratique des Phlox," which describes in detail the culture, breeding, and ideal types of phlox, citing numerous examples of each.

Of the many varieties introduced between 1850 and 1875, *Crepuscule* (Fontaine) is still common in our gardens though *La Candeur* (Lierval), *Bicolor* (Rodigas), *Amphytrion* (Rodigas), *Magnificence* (Fontaine), *Belle Pyramid* (Rendatler), *Duguesclin* (Lemoine), and *Fernand Cortes* (Lemoine) are still to be found in the trade.

After the death of Lierval in the Franco-Prussian war, interest in phlox shifted to the south of France where Chretien originated a dwarf type of *P. decussata*. In 1875 Crozy introduced six dwarf varieties raised by Denis from the old variety *Gloire de Lyon*.

Dwarf varieties of any type were very popular. Lemoine (23) developed a race of *P. suffruticosa* adapted to treatment as an annual and raised from seed. *Comtesse de Jarnac* (21) was a mutant secured by Courin 1890 from a named variety on which it developed as a side branch. Its dwarf habit is due to the numerous white blotches characteristic of its foliage. Ferdinand Lahaye (Gerbeau) was obtained from seed and though its foliage was strongly mottled in the young plants, it became normal green at maturity. *Gloire de Orleans* is another variety of this general class.

In America the initial plantings were doubtless made in the early colonial gardens of Virginia and Carolina. Following the period of importation of phlox species to Europe, Botanical gardens were founded at Philadelphia, Charleston, New York, and Cambridge. The records of these gardens in the early nineteenth century contain several references to phlox. The most complete list, published by Muhlenberg (17) in 1813, includes eighteen species.

As early as 1820 European hybrids were imported by American nurserymen, Prince Buist, and Hovey among the leaders. Joseph Breck (3) and William Carter raised and introduced seedlings of *P. paniculata* as early as 1837 and by 1850 Breck had raised several thousand seedlings of which about 50 were introduced into the American trade. Of these early introductions *Breckii* (Breck), *Frelinghy-sen* (Carter), *Henry Clay* (Carter), and *Perfection* (Breck) were the most important.

European varieties have always played the greater rôle in the American trade (9). R. P. Struthers (Rea) is one of the few American varieties to be generally grown. Riverston Jewell (Dreer), Debs, Maid Marion, and Ruby, all Thurlow introductions, are also well known. Massachusetts remains the center of interest in phlox breeding, though Fryer, in Minnesota, and Andrews in Colorado have introduced a number of varieties. Schmeiske, of Kirkwood, New York, has combined the disease-free growth and the flowering habit of the dwarf varieties with the taller and more abundant growth of the *P. decussata* hybrids, the varieties Mrs. Harding and Mrs. Far-land are particularly outstanding.

The majority of the foreign varieties in the present American trade are from Lemoine, Pfitzer, Ruys, Goos and Koenemann, Arends, Jones, and Aldersey.

A list of the early American varieties is given below:

Variety	Originator	Date	Color	Eye
Alata Alba	Carter	1838	white	
America	Breck	1856	blush	peach blossom
Azurea compacta	Ellw. & By.	1867	white	purple
Blanche	Hovey	1852	white	pencilled
Breckii	Breck	1837	white	red
Carnea	Carter	1845	incarnate	
Carterii	Carter	1838	white	
Estella	Walker	1844	lilac purple	
Florence	Hovey	1852	blush	carmine
Frelinghysen	Carter	1844	striped	
Gem	Hovey	1852	rose	light
Grandiflora	Breck	1852	lavender	
Harrisonii	Carter	1840	white	
Henry Clay	Carter	1844	dark penciled	
Lawrencia	Carter	1852	white	
Mrs. Breck	Breck	1856	red	deep eye
Mrs. Buist	Buist	1857	white	
Mrs. Webster	Breck	1853	white	
Perfection	Breck	1852	white, striped and edged red	
Resplendent	Hovey	1854	rose	
Richardsonii	Richardson	1842	red	
Richardson's Purple	Richardson	1844	purple	
Richardson's Crimson	Richardson	1844	crimson	
Russelliana	Carter	1844		
Striata albicans	Ellw. & By.	1867	white	purple striped
Striatiflora	Carter	1843	striped	
Variegata	Breck	1852		
Wilderii	Breck	1851	dark red	

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Peony Fertilizers and Cutting Methods

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FERTILIZER EXPERIMENT

THE growing of peonies for cut flowers has become an important industry in southern Illinois and Indiana and to a lesser extent in the vicinity of the larger cities. The growers are confronted with the problem of the proper fertilizers to use. In order to aid in securing information, a fertilizer experiment was outlined.

An area of fertile brown silt loam was prepared for a peony plantation during the summer of 1925. On one section a cover crop was grown and plowed under in early fall. The remainder of the area received well rotted manure at the rate of 20 tons to the acre.

On November 10 and 11 one row each of seven varieties of peonies were planted in rows 4 feet apart, with plants at 3-foot intervals. The plants were selected for uniformity from a 1-year-old plantation. Fertilizer plots were laid out at right angles to these rows so as to contain 4 or 5 plants of a variety in a plot and with three plants of a variety between plots. The center plant in the area between plots was used as a check.

Plots 1 to 5, inclusive, received manure in 1925, while plots 6, 7, and 8 had a cover crop plowed under. Fertilizers were applied annually to all plots, except 6 and 7, about the time growth started. The fertilizers were broadcast within a radius of 12 to 15 inches about the plants and worked into the soil. The annual applications per acre were as follows:

- Plot 1 Well rotted manure, 20 tons
- Plot 2 Well rotted manure, 20 tons
Steamed bone, 500 pounds
- Plot 3 Steamed bone, 500 pounds
Sodium nitrate, 200 pounds
- Plot 4 Sodium nitrate, 200 pounds
Superphosphate, 750 pounds
- Plot 5 A 4-inch mulch of straw manure each fall.
Not removed
- Plot 6 No treatment after cover crop was plowed under
- Plot 7 Steamed bone, 500 pounds
Sodium nitrate, 200 pounds
- Plot 8 Steamed bone, 500 pounds
Sodium nitrate, 200 pounds
Potassium sulfate, 200 pounds.

In the spring of 1926 all buds were removed so as to throw the strength of the plants into vegetative growth. In 1927, 28 per cent of

the plants flowered, producing an average of seven blooms. The plants which flowered were scattered throughout the plantation.

During the first few years of the experiment, nitrate of soda had a noticeable effect in improving the size and the color of the foliage. Manure had a similar effect, but where it was used freely there was excess of foliage, inferior flowers, weak stems and a tendency for the stems to rot at the base.

TABLE I—SHOOT GROWTH AND FLOWER PRODUCTION OF PEONIES WITH DIFFERENT FERTILIZER TREATMENTS

Plot ¹	Shoots per Plant				Flowers per Plant			
	1928 ²	1929	1930	1931	1928	1929	1930	1931
1	24.7	28.1	28.0	30.7	11.8	18.9	12.6	19.7
2	24.6	32.9	28.2	28.5	12.3	26.2	11.1	20.2
3	29.5	30.9	31.1	34.0	11.4	25.2	11.9	23.8
4	29.9	36.0	35.7	36.7	14.2	24.1	15.0	24.5
5	28.3	37.3	36.2	38.4	9.0	26.4	11.6	22.2
6	25.3	29.1	29.3	32.2	16.9	21.7	18.6	26.1
7	23.7	28.3	25.2	27.5	9.8	19.1	11.7	19.3
8	23.0	25.7	21.5	26.0	11.4	19.6	13.5	22.9
Check	22.7	27.9	28.5	30.9	12.1	23.8	16.3	23.9

¹Plots 1 to 5, inclusive, received an application of manure, 20 tons to the acre, before planting. Plots 6, 7 and 8 had a cover crop plowed under before planting.

²Average for five varieties instead of seven.

Plots 3 and 4, which received nitrate of soda, and plot 5, which received a strawy mulch in the fall, showed a stronger vegetative growth than the checks (Table I). The other plots varied slightly, but not consistently nor significantly from the checks. The average yields of blooms from plots 3, 4, and 5, however, were less than the average from the checks (Table I). The heavy manure mulch (plot 5) caused rapid spring growth, weak stems and poor flowers.

The differences from season to season between the average yields from the several treatments were inconsistent. Average results for four seasons showed yields from the untreated plots as high as or higher than the yields from any of the fertilizer treatments. These results indicate that peonies planted on a fertile soil are not likely to respond profitably to applications of fertilizer for some years at least.

CUTTING EXPERIMENT

A cutting experiment was started because there was little information available on the effects of heavy cutting on the health and vigor of the plants.

In the fall of 1924 a commercial planting of seven varieties commonly grown for cut flowers was made in a fertile brown silt loam soil. The plants were set in rows four feet apart and 3 feet apart in the row. They were allowed to grow normally until the spring of 1927 when the cutting experiment was begun. No fertilizers were used after the peonies were planted.

Four plants of a variety, 28 plants in all, were cut so that one-half

of the shoots on each plant were cut to the ground. In another plot of equal size, all of the shoots on each plant were cut so as to leave three leaves on each shoot. The yields from these plots were compared to the yields from a plot of equal size from which no blooms were cut.

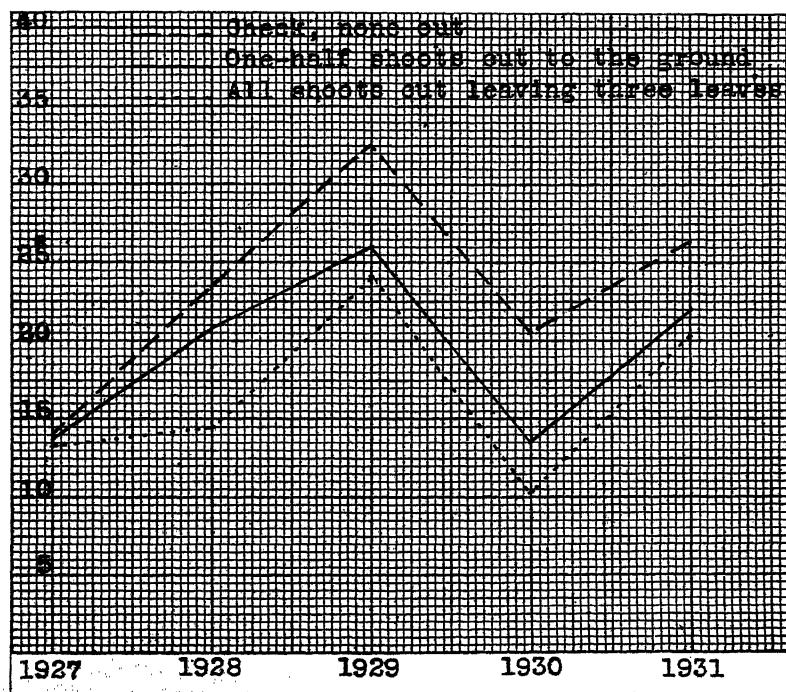


FIG. 1. Flower production of peonies with different methods of cutting.

At the beginning of the experiment the plants in the different plots were practically uniform in size. The total number of shoots were reduced some by cutting as compared to plants where no blooms were cut, but this reduction was not so great as might be expected.

A study of flower production, however, shows that both cutting methods reduced the average number of blooms per plant. Cutting all shoots, leaving three leaves to the shoot, reduced flower production to a greater extent than when one-half of the shoots were cut to the ground.

A larger number of flowers were harvested where all of the shoots were cut, as compared with plants from which only half of the shoots were cut, but the stems were shorter. There were no great differences in the vigor of the plants in the two plots. Commercially these cutting

methods should be modified to meet the demands of the markets for stem length.

No differences were noted in the quality of blooms produced by plants of the same variety in the different plots. Varieties differed greatly in flower and shoot production. Flower production at the beginning of the experiment, varied from 9 to 24 blooms per plant with the variety. In 1931 the yields of different varieties in the check plot were 20 to 34 blooms per plant.

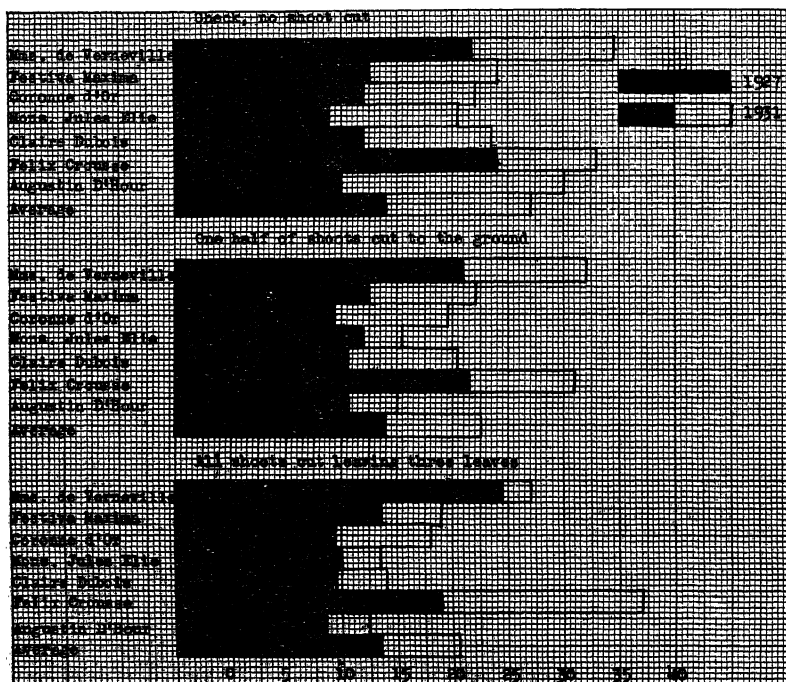


FIG. 2. Flower production of peonies in 1927 and in 1931 with different methods of cutting.

Peonies vary in flower production from season to season (Fig. 1). In the spring of 1929 flower production was high. This was followed by a much lower production in 1930, due principally to a late frost that killed many of the buds.

All varieties, regardless of treatment, produced more flowers in 1931 than at the beginning of the experiment in 1927 (Fig. 2). Varieties varied considerably in this respect. The average increase for the check plot was 86 per cent, while for "one-half of the shoots cut," and "all shoots cut" the increases were 58 and 51 per cent respectively.

Cutting the blooms as described did not seem to make the plants more subject to disease. No ill effects were noted from cutting stems at the surface of the ground.

The Use of Washed Sand as a Substitute for Soil in Greenhouse Culture

By ALEX LAURIE, *Ohio State University, Columbus, Ohio*

THE laboratory technique for the determination of the needed elements for plant nutrition was developed through the initial efforts of Sachs, Knop and Nobbe (1859-1865), although the earliest recorded experiment with water cultures dates back to the work of Woodward (1699). In more recent times, Schrimper, Pfeffer, Crone, Hoagland and others have contributed a great deal to our sum total of knowledge relative to nutrient solutions and their use. A comparative study of sand and water cultures as media for plant growth was made by McCall, Hall, Shive, Bakke, Hoagland and others and the consensus of opinion seems to be that sand furnishes a medium more comparable to actual soil conditions than water. Practically all investigators agree that growth of roots is more profuse in sand than in unaerated water, a fact which has been generally attributed to the greater aeration in sand.

Pember and Adams (1921) studying the influence of physical factors and various fertilizer chemicals on the growth of carnations, found that these plants grown in sand, to which nitrogen, potassium, and phosphorus were added, produced a greater number of first quality flowers than those in soil to which similar chemicals and manure were applied. Likewise, additions of commercial peat to sand affected the plots beneficially, a fact which these workers believed to be due to the prevention of excessive leaching of the added nutrients.

More recently Nightingale and Connors working in New Jersey with carnations and roses, have shown the feasibility of the use of sand together with nutrients in place of a soil medium. Their results apparently justify the claim that sand may be used as a substitute for soil in commercial practice.

Bearing these results in mind and recognizing the difficulties attendant to recommendations for fertilizer treatments in varying soil media, the writer started a series of tests with sand cultures in 1928 using snapdragons, carnations, sweet peas and a number of bedding plants. These preliminary tests indicated the possibilities which lay ahead. In 1929, 1930, and 1931 a number of experiments were started at Ohio State University, using washed sand in benches and pots. In place of using nutrient solutions, the chemicals were applied in dried form in order to approximate as closely as possible present commercial practices. When planted in benches or in pots the soil was washed from the roots of the plants to eliminate any organic matter as well as the influence of the nutrients contained in the soil. However a series of plots were also run with Snapdragon and Calendula from roots of which soil was not washed. Apparently there was not the slightest difference in the ultimate results secured. The small amount

of soil (2½-inch pots) had no advantage over the washed roots. This fact was established primarily in order to facilitate the handling of such stock in commercial practice.

Table I indicates results secured in one of the earlier tests with calendulas.

TABLE I—COMPARISON OF SOIL AND SAND MEDIA FOR CALENDULAS

Treatment	Variety	Av. No. Flowers per Plant	Stem Length (Inches)	Diameter of Flower (Inches)
Sand + 4-12-4 (weekly) . . .	Imperial Gold	5.10	16.9	3.1
	Imperial Orange	4.95	15.3	2.6
Soil + 4-12-4 (weekly)	Imperial Gold	4.18	16.01	2.8
	Imperial Orange	4.95	13.2	2.4

Imperial Gold showed a decided increase in production in sand as well as a slight increase in stem length and size of flower. In Imperial Orange the difference was most marked in stem length. The stiffness of the stem as well as the keeping qualities of the crops in sand and soil did not differ.

Another series of tests were started in December 1930, using the following annuals, namely, Schizanthus, Snapdragons, Calendulas, Stocks, and Larkspur. All these were planted from 2½-inch pots. The medium used was washed bank sand. Applications of fertilizers were made at the rate of 4 pounds per 100 square feet of bench space, at weekly intervals, with the exception of 15-30-15, which was applied at one-half the above rate. The results are shown in Table II.

The results secured from Schizanthus and Larkspur plots were based on the check as 100 since it was difficult to keep accurate records of these two plants. It will be noted that in general the first eight plots showed a decided increase in growth and production over the balance. This might be attributed to the presence of humus. The response of the different types of plants was varied but in general the reaction to fertilizer applications was satisfactory. Sedge peat gave better results in practically all cases than sphagnum peat, due to the higher nitrogen content of the former and its further stage of decomposition. Fresh manure checked the growth during the early stages, due to the bacterial action in decomposition which deprived the plants of needed nutrients. Later normal growth developed. The pure sand plots to which fertilizers containing organic nitrogen were applied gave the best results (Plots 9 and 10).

During the present season (1931) a series of comprehensive tests were started with chrysanthemums, carnations, snapdragons, calendulas, stocks, cinerarias, primroses, calla lilies, tulips, narcissi, hydrangeas, asparagus sprengeri, and others.

Table III indicates the plots used and the results obtained with chrysanthemums. Silver Sheen and Gladys Pearson varieties were spaced 8 inches each way in benches, filled with media 5 inches deep.

TABLE II.—RESPONSE OF ANNUALS IN BANK SAND TO FERTILIZER APPLICATION

Plot	Treatment	Schizanthus	Larkspur	Snapdragons		Stocks		Calendulas		
				No.	Length (Inches)	No.	Length (Inches)	No.	Length (Inches)	Diameter (Inches)
1	Soil, check	100	100	6.2	17.9		27.0	5.8	12.0	2.5
2	1/4 Sand, 1/4 manure	85	80	5.6	23.5		26.8	5.2	10.9	2.4
3	1/4 Sand, 1/4 manure, Vigoro (4-12-4)	120	90	5.6	20.7		25.2	4.4	10.1	1.9
4	1/4 Sand, 1/4 manure, 1/4 sedge peat	105	90	6.4	28.9		29.5	5.4	11.9	2.5
5	1/4 Sand, 1/4 manure, 1/4 sphagnum peat	85	85	5.6	27.7		24.8	5.6	10.3	2.4
6	1/4 Sand, 1/4 sphagnum peat	80	85	2.8	31.7		21.6	3.6	10.0	2.7
7	1/4 Sand, 1/4 sedge peat, Vigoro	98	85	3.7	24.2		26.0	4.0	12.4	2.5
8	1/4 Sand, 1/4 sedge peat	98	85	8.4	23.6		25.0	5.0	11.6	2.5
9	Sand, Bloomaid (5-10-4)	95	85	7.0	21.1		28.8	4.9	10.2	2.4
10	Sand, Sacco (4-12-4)	85	85	4.2	20.4		25.6	4.4	10.5	2.5
11	Sand, 15-30-15	60	55	3.2	16.3		22.4	4.6	10.9	2.3
12	Sand, Turf Builder (10-6-4)	65	60	4.2	15.6		23.2	5.6	8.0	2.3
13	Sand, 10-6-4	60	60	2.0	15.2		22.0	4.6	8.2	2.3
14	Sand, 4-12-4	45	60	2.6	17.9		17.8	5.4	10.6	2.4
15	Sand, Vigoro	70	55	3.2	19.2		23.3	4.4	12.2	2.3

The ratios of nutrients indicated were applied at weekly intervals until the flowers showed color. Two stems were grown to a plant. Ammonium sulphate, superphosphate (45 per cent), and potassium chloride were used in making the varying mixtures.

TABLE III—RESULTS WITH CHRYSANTHEMUMS

Treatment	Silver Sheen		Gladys Pearson	
	Stem Length	Diameter of Flower	Stem Length	Diameter of Flower
Sand, Sacco.....	35.4	4.8	50	5.4
Sand, Vigoro.....	35.1	4.1	46.5	5.08
Sand, 1-2-6.....	36.8	4.5	45.1	5.6
Sand, 1-2-4.....	36.3	4.7	50	5.6
Sand, 1-2-2.....	37.4	5	50.8	5.5
Sand, 4-2-1.....	35.6	5	45.8	5.3
Sand, 3-2-1.....	36.2	4.8	45.9	5.3
Sand, 2-2-1.....	38.7	4.8	48.8	5.5
Sand, 1-6-1.....	37.5	4.8	50.7	5.7
Sand, 1-4-1.....	38.8	5	50.2	5.8
Sand, 1-2-1.....	39.3	4.9	50.8	5.8
Sand, peat.....	37.3	5	50.6	5.6
Soil.....	34.8	4.5	45.9	5.6
Sand, peat, Sacco.....	34.4	4.4	47.2	5.6
Sand, peat, Vigoro.....	34.7	4.6	38.3	5.3
Sand, peat, 1-2-6.....	34.2	4.4	45	5.8
Sand, peat, 1-2-4.....	34.1	4.7	44.4	5.6
Sand, peat, 1-2-2.....	35.1	4.6	48.3	5.8
Sand, peat, 4-2-1.....	33.5	4.5	37.4	5.8
Sand, peat, 3-2-1.....	34.5	4.2	45.8	5.9
Sand, peat, 2-2-1.....	35.3	4.4	43.3	5.4
Sand, peat, 1-6-1.....	36.2	4.4	49.3	5.5
Sand, peat, 1-4-1.....	36.1	4.4	52.8	5.3
Sand, peat, 1-2-1.....	34.4	4.5	49.6	5.6

The differences secured in this series of plots are insignificant in themselves, except that indication is given of the feasibility of sand cultures. The stem lengths as well as diameters of the flowers are comparable to those obtained from several check plots which have been averaged into one. The variations in ratios have had little significance, which may be due to the fact that even the lowest may be sufficient in themselves and that higher nutritive values are not necessary. Again the frequency of application may have been too great. In this series of tests, it will be observed that additions of humus produced no beneficial effect. This contradicts the conclusions from previous tests and again may be due to too frequent addition of nutrients.

The conclusions to be drawn from these preliminary tests are negligible in so far as fundamental information is concerned and the problem is being attacked now from several other angles. However, from the standpoint of practical application it looks promising since it is apparent that washed sand may be used as a substitute for soil in commercial practice as soon as the details of the amounts of nutrients,

then ratios, and the frequency of applications are solved. From the practical standpoint sand is advantageous because yearly replacement may be eliminated, because accumulation of soluble salts may be avoided, because known quantities of fertilizers at specified periods need not vary from year to year, because control of soil moisture may be simplified, because soil aeration troubles may be reduced, and finally because thorough drenching and sterilization of the sand after use may eliminate soil pests. From the scientific viewpoint, it is the only accurate method of approach to the problem of nutrition, since recommendations based on soil plot methods are not always applicable to all conditions and environments.

Effects of the Application of Nutrients to Ornamental Trees

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THE application of nutrients to ornamental trees is not a new subject of investigation but studies in this direction have yielded results of little apparent value. The selection of carriers of nutrients and the proper time of their application is of great importance.

In this preliminary study established young trees of the English Elm (*Ulmus campestris*) and Sugar Maple (*Acer saccharum*) were selected. These trees were located on the campus of Ohio State University and were of uniform size, about 25 feet in height. Twenty plots of 15 trees each were laid out and received the nutrients indicated in Table I. Nutrient materials were applied in the fall, the second week of October, and in the spring the third week of April. Applications were made at the rate of one-half pound of nutrient material for every inch in diameter of the tree, the measurements being taken 2 feet above the ground. The nutrients were spread about the base of the trees, covering approximately the same area covered by the spread of the branches. Measurements were taken of 25 twigs on each tree and the average was computed and presented in Table I. The trunk caliper given is the average of the 15 trees. Measurements were taken in October and again in August.

The data secured from this study show that the application of quickly available nitrates produces the most appreciable increase in caliper and length. Nitrate of soda and ammonium sulphate gave much the same increase in caliper and length growth for both fall and spring applications. With *Ulmus campestris* the increase in twig length for each case was about nine times that of the check plot.

The spring application for both of these nutrients proved the most beneficial. This is due to the facts that they are quickly available and applied at a time when they may be used by the plant. *Ulmus campestris* and *Acer saccharum* reacted much the same to these two nutrients although the increase in length-growth was even more striking with *Acer saccharum*. The treated plots show an increase of from 15 to 20 times that made by the check plot. In this case, nitrate of soda gave best results when applied in the fall.

The application of superphosphate showed very little increase in growth over the check. This was no doubt due to the fact that phosphoric acid penetrates very slowly, less than 1 inch per year, and probably had not penetrated to the roots of the trees, or had been used up by the vegetation under them. The new growth on the trees to which superphosphate was applied showed a striking yellow color in comparison with the others. This may have been due to the lack of penetration of the superphosphate and an absence of sufficient nitrogen. The checks, however, did not show this striking yellow color.

TABLE I—EFFECTS OF THE APPLICATION OF NUTRIENTS TO ORNAMENTAL TREES

Nutrient	Plant	Season of Application	Twig Length (Centimeters)			Twig Caliper (Centimeters)			Trunk Caliper (Centimeters)		
			Oct.	Aug.	Difference	Oct.	Aug.	Difference	Oct.	Aug.	Difference
Check.....	Elm	—	12.32	14.78	2.46	.17	.23	.06	15.25	17.45	2.20
Nitrate of Soda.....	Elm	Fall Spring	15.93 12.10	33.49 34.67	17.56 22.57	.23 .19	.35 .37	.12 .18	12.24 10.70	15.44 13.10	3.20 2.40
Ammonium sulphate.....	Elm	Fall Spring	11.14 10.97	31.70 32.58	20.56 21.61	.17 .20	.31 .31	.14 .11	13.37 13.90	15.67 16.30	2.30 2.40
20 per cent superphosphate	Elm	Fall Spring	9.38 9.34	11.22 13.29	1.84 3.95	.18 .17	.22 .19	.04 .02	9.85 18.10	11.02 20.20	1.17 2.10
Shredded sheep manure....	Elm	Fall Spring	10.70 11.22	12.84 15.00	2.14 3.78	.22 .19	.24 .23	.02 .04	11.32 13.12	13.75 16.90	2.43 3.78
4-12-4 Inorganic.....	Elm	Fall Spring	8.65 10.37	19.43 26.71	10.78 16.34	.16 .17	.30 .19	.14 .12	13.42 13.40	16.22 16.27	2.80 2.87
10-6-4 Organic.....	Elm	Fall Spring	14.43 15.67	27.83 28.16	13.40 12.49	.24 .20	.34 .36	.10 .16	17.32 13.82	20.75 16.47	3.43 2.65
Check.....	Maple	—	10.25	10.42	.17	.25	.29	.04	14.70	15.80	1.10
Nitrate of Soda.....	Maple	Fall Spring	11.85 16.68	36.32 32.35	24.47 15.67	.34 .31	.41 .39	.07 .08	17.75 15.25	21.52 19.47	3.77 4.22
Shredded sheep manure....	Maple	Fall Spring	10.00 11.38	23.27 19.74	13.27 8.36	.26 .30	.36 .39	.10 .09	11.15 15.62	13.00 17.50	1.85 1.88
4-12-4.....	Maple	Fall Spring	10.53 10.03	23.30 28.73	12.77 18.70	.29 .36	.36 .41	.07 .05	14.30 14.12	16.52 17.30	2.22 3.18

The plots to which shredded sheep manure was applied showed a slight increase over the check. This increase was very small in comparison to the plots upon which nitrate carriers were applied. This organic material is much more slowly available and the amount of available nitrogen in this carrier is much less than in nitrate of soda and ammonium sulphate. As shown with *Acer saccharum*, fall applications should be the most beneficial.

The plots to which a balanced 4-12-4 fertilizer was applied showed a stimulated growth both of stem length and caliper. The plots receiving the fall application showed an increase in growth of 8.32 cm. over check in twig length, and the spring application showed an increase of 13.88 cm. This again brings out the desirability of spring application of inorganic fertilizers. The beneficial results derived from this complete fertilizer is without doubt due to the nitrogen content because, as has been shown, superphosphate had little effect on these trees.

The 10-6-4 balanced fertilizer gave much the same increase in growth as 4-12-4. In this case, however, the greatest increase in growth was shown by the plot on which the nutrient material was applied in the fall. This is due to the fact that the carriers used in this complete fertilizer were organic in nature and became available more slowly. Fall application would tend to be the more desirable.

The results obtained by this investigation are such that the general conclusions drawn could not be used for specific recommendations for every situation. The problem would have to be carried over a much greater period of time than one year to obtain comprehensive data. The soils in different localities as well as the environmental conditions would have a varying effect upon results secured.

The following conclusions may be drawn: (1) The application of nitrate of soda and ammonium sulphate produced the most appreciable increase in growth; (2) spring applications are more beneficial than fall treatments except with nutrient materials that are slowly available; (3) the application of phosphoric acid produced little additional growth; (4) the application of a complete fertilizer showed increase in growth, due to its available nitrogen content; and (5) more quickly available nutrients such as nitrate of soda and ammonium sulphate produce much greater results than do the more slowly available sort, such as shredded sheep manure or organic carriers used in preparing the 10-6-4 formula used in this investigation.

Growth Experiments with Shade Trees Under Lawn Conditions

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ONLY recently have careful growth experiments with shade trees been undertaken. Many experiments have been reported on the factors necessary for hastening the vegetative growth of fruit trees. After a thorough review of these, it was thought wise to initiate growth experiments with shade trees which are under lawn conditions. The average home owner is often unable to pay the price necessary for moving mature trees to his property, but when he plants a smaller tree, he wants growth to proceed at a maximum rate. His shade trees are usually growing in the lawn, where the influence of the grass sod must be considered. The object of the experiments here reported is to investigate the factors contributing to a maximum growth of such trees in a minimum time. This paper is to be considered chiefly as a progress report, since the experiments here reported were started only one year ago.

In 1904 Pickering (3) concluded from experiments with young fruit tree seedlings, that the orthodox method of careful tree planting was unnecessary; that "careless planting," when the roots were often injured and jammed into a shallow, narrow hole with the soil firmly tamped on top of them, led to better growth than careful planting, and that this held true in every case on many different soil types and that these differences in growth held for at least 8 years after planting. His most accurate experiments were those in which he used tree weight as a basis for his comparisons.

Lyon, Heinicke, and Wilson (2) report a marked response in vegetative growth in Western New York from the use of nitrogen on young apple trees standing in sod, with no significant differences where trees were cultivated. Nitrate nitrogen is deficient in sod and this deficiency is more important than loss of water by the sod. In the Hudson Valley, Tukey (5) found, by applying various amounts of NaNO_3 to one- and two-year-old apple trees at time of planting, that trees grew best without fertilizer or only $\frac{1}{2}$ pound applied well back from the tree. Larger amounts were injurious. Later he found that with several different kinds of fertilizers applied in various amounts at time of transplanting, those trees grew best which received no fertilizer or only small amounts of urea. Tukey's experiments were carried out on land under cultivation. Since it is generally accepted that potash in most soils is sufficient for vegetative tree growth, it is not used in the experiments reported in this paper.

Any pruning of the tops, so long as roots are undisturbed, decreases vegetative growth as compared with the growth made by a similar unpruned tree, but pruning at planting time is absolutely necessary

as Pickering showed, when he concluded from his experiments that the trees left unpruned after transplanting did not form new growth on branches and roots nearly as fast as those pruned at transplanting time.

Heinicke (1), Swingle (4), and others have noted the marked variability in growth of apple seedlings of the same age. The tendency is for the largest seedling to give the largest tree. This important fact has been noted in oak tree seedlings as well as seedlings of many other shade trees. Consequently, any growth experiments with trees should include trees not only of the same age but also having a similar growth performance over a period of years. This is a most important point, as some recent shade tree fertilizing experiments have been carried out on trees of unknown age and growth performance, but which were "apparently similar."

MATERIALS AND METHODS

Pin oak trees (*Quercus pulustris*) were selected for this experiment because they are a valuable slow-growing type. The trees selected were 5 years old, all grown in the same plot from the same lot of seed and were selected for their uniform caliper and size. Duplicate experiments, set out in November 1930, are being run on a Dunkirk stony clay, and on a Dunkirk silty clay loam. These plantings were duplicated in the spring of 1931 to provide fall and spring planted experiments on two soil types. These include some 400 trees, planted 12 feet x 12 feet, all in a closely cut Kentucky blue grass sod.

Planting studies comprised three lots of trees, namely, (A) planting in a deep wide hole with soil simply thrown in loosely on top of roots; (B) planting roughly, in extremely narrow, shallow hole, roots often badly injured and jammed together, soil tamped in on top of roots with a post hole tamper; and (C) planting in customary manner, in deep, wide holes, soil loosened at bottom of hole with pick, roots carefully placed with plenty of room and with soil firmly packed with feet but not tamped.

Fertilizing studies comprised lots receiving (D) 8 ounces of ammonium sulphate per tree at time of planting, May, 1931; (E) 8 ounces of ammonium sulphate per tree September 1931, to trees planted one year previous; (F) 12.6 ounces amophos (13-46-0) applied per tree at time of planting, May 1931; (G) 12.6 ounces amophos (13-46-0) applied per tree in September 1931, to trees planted one year previous; (H) checks, unfertilized.

Pruning studies comprised lots: (I) receiving no pruning at time of planting; (J) trees pruned at time of planting, with remaining branches at top of trunk; and (K) trees pruned to a similar amount, but with branches left all along the trunk.

As is consistent with commercial practice, all fertilizers were applied in holes made with a crow bar, 2½ feet from the trunk. The

fertilizer must not injure the grass, or be utilized by the grass. In either event, it would obviously spoil the conditions of the experiment.

TABLE I—EFFECT OF TIME AND MANNER OF PLANTING ON NUMBER OF TREES PARTLY OR ENTIRELY DEAD

Soil Type	Time of Planting	(A) Loose Planting	(B) Rough Planting	(C) Ordinary Planting	Per cent Loss
Gravelly....	Spring	2	1	2	11.1
Gravelly....	Fall	3	3	2	17.7
Clay.....	Spring	0	2	1	6.6
Clay.....	Fall	4	1	1	13.3
Per cent loss.	—	15	11.6	10	—

All trees, other than those specifically excepted were planted in the customary large holes and carefully pruned at time of planting. After pruning, the height of most trees was 4 to 5 feet. The trees used in the pruning experiments were 6 to 7 feet tall. Instead of planting trees of one experiment in a single row, trees of any group of experiments were located at various places in the plot, to diminish the effect of any possible soil variations. For instance, lots A, B, and C were grouped together 15 times on each of the four experimental plots.

Measurements were taken at time of planting and in November, 1931, after growth had ceased, of caliper, tree height, total elongation of all branches, number of growing points and tree spread. Since *Quercus palustris* tends to have an irregular trunk at this age and since the diameter increase in most cases this first year was not over $1\frac{1}{2}$ mm., the error incident to such minute measurements is rather high. Consequently the results of the growth for the first year will be calculated from total elongation of all branches.

RESULTS

Using Love's modification of the Student Method, the odds are 69.4 : 1 in favor of spring planting, calculated on a basis of growth alone. Furthermore, 16.5 per cent of all trees planted in the fall were either killed or died back, as compared with only 9.5 per cent of those planted in the spring. Naturally, some of the losses in both cases were due to experimental conditions, but this difference is significant.

In Table II, the significant differences brought out are that on gravelly soil, spring planting should be done in the ordinary manner, (Lot C). Trees planted loosely (Lot A), or roughly (Lot B) were unable to withstand the dry weather which came about 1 month after planting. In many cases with the roughly planted trees (Lot B) the leaves wilted and dropped. The difference in growth between spring and fall planted trees is significant; other differences were not.

TABLE II—EFFECT OF TIME AND MANNER OF PLANTING ON LINEAR GROWTH (IN FEET)

Soil Type	Time of Planting	(A) Loose Planting	(B) Rough Planting	(C) Ordinary Planting
Gravelly.....	Spring	2.80	2.35	4.00
Gravelly.....	Fall	2.45	2.13	2.65
Clay.....	Spring	2.47	2.94	2.81
Clay.....	Fall	1.90	2.44	2.42

With the experiments in fertilizing trees at time of transplanting no trees were killed by the fertilizers, though marked burning of leaves was noted in some cases. Since the fertilizers in lots E and G were not applied until September 1931 after current growth had ceased, no results were evident at time of writing.

TABLE III—EFFECT OF FERTILIZER APPLICATION AT TIME OF PLANTING ON LINEAR GROWTH (IN FEET)

Soil Type	Time of Planting	(C) Check	(D) Am. Sulphate 8 Ounces	(F) Amophos 12.6 Ounces
Gravelly.....	Spring	3.96	2.88	2.61
Clay.....	Spring	3.27	2.83	2.42

The differences above are not significant and carry out Tukey's (5) conclusions from experiments with young fruit trees that fertilizer applications at time of planting are not beneficial. However, it must be kept in mind that since the fertilizer has been in the ground only 5 months, delayed differences may appear next spring.

TABLE IV—EFFECT OF PRUNING AT TIME OF PLANTING ON NUMBER OF TREES PARTLY OR ENTIRELY DEAD

Soil Type	Time of Planting	(I) No Pruning	(J) Branches at Top of Trunk	(K) Branches all Along Trunk	Per cent Loss
Clay.....	Fall	3	3	3	30
Clay.....	Spring	4	1	0	18.5
Per cent loss.	—	35	20	15	—

The smaller growth and the large mortality for the unpruned trees, is of course significant. Differences from a comparison of the two types of pruning will probably not be evident for some time.

TABLE V—EFFECT OF PRUNING AT TIME OF PLANTING ON LINEAR GROWTH (IN FEET)

Soil Type	Time of Planting	(I) No Pruning	(J) Branches at Top of Trunk	(K) Branches all Along Trunk
Clay.....	Fall	2.20	3.88	3.20
Clay.....	Spring	2.48	2.56	3.57

CONCLUSIONS

In every case, the spring planted trees made more growth than those planted in the fall. Of the fall planted trees, 19.5 per cent were killed or died back to within a foot of the ground, and only 9.5 per cent of the spring planted trees. As it happened, the fall of 1930 was very dry, and the trees planted in November were set in fairly dry soil. The trees planted in May, however, were started under ideal soil and weather conditions.

Trees planted in the spring on a stony clay soil grew best when planted in the ordinary manner. Those planted in holes in which the soil was simply thrown in and not firmed, were not able to grow well during the dry spell which followed a month after planting, probably because of the rapidity with which the soil dried out. Trees firmly tamped in did not do well, probably because the holes were only about 6 inches deep, while the properly made holes were three to four times this depth. This shallowness caused them to dry out easily.

No significant differences on growth resulted from the three methods of planting on the silty clay loam. It is interesting to note (Table I) that fewer trees died in the silty clay loam soil, whether planted in fall or in spring, than in the stony clay soil. This is probably because the latter soil type is much looser and dries out more quickly.

Neither 8 ounces of ammonium sulphate nor 12.6 ounces amophos, applied in holes $2\frac{1}{2}$ feet from the base of the tree at time of transplanting had a beneficial effect, and in some cases leaf burning was evident. It is possible that significant differences may appear another year.

Trees which are not pruned at time of spring transplanting die much more readily than those which are pruned. This difference is not apparent in the fall transplanted trees, probably for the reason that roots do not cease growth when the leaves drop, but continue growth until freezing weather. This would enable the roots of both pruned and unpruned trees to get an approximately equal start in the dormant period. In spring planting, however, with the appearance of the leaves immediately after transplanting, the roots on the pruned trees can not get this equal start. Consequently the roots of the unpruned tree cannot supply all the breaking leaf buds with water and nitrates. A large proportion of the unpruned twigs, therefore, die back, and this process of equalization between tops and roots takes time. As a result, the tops are unable to make as much new top growth as the pruned trees. Pickering (3) noted a similar retardation of root development in the unpruned tree, corresponding with the slower top growth.

These conclusions must be considered solely as the first year's results of a long time experiment. Weather conditions, naturally, must have had something to do with the success or failure of some of these experiments, and it is only by repeating these, over a period of

years, possibly using several types of shade trees, that any definite conclusions can be reached regarding fundamental practices.

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Effects of Temperature and Desiccation During Storage on Germination of Seeds of the American Elm (*Ulmus americana* L.)¹

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IN performing experiments with plants it is frequently desirable to grow several lots of seedlings at various times of the year. With such short-lived seeds as the elm it is of importance to know how to preserve the viability of the seed until it is to be used.

In experiments at University Farm, St. Paul, on elm seedlings, one of the authors observed that a certain lot of elm seed which he had stored in a tightly stoppered bottle for a number of months, germinated much better than similar seed which had been exposed to the air for the same period. The experiment here reported was an outgrowth of this observation and was designed primarily to determine the effects of desiccation and temperature upon the viability of seeds stored in closed containers.

On May 29, 1929, a large quantity of seed was obtained from a number of American elm trees growing in Como Park, St. Paul. The seed was taken to the Plant Physiology Laboratory at University Farm where it was allowed to stand until June 7 when the entire quantity of seed was thoroughly mixed and divided into aliquots of suitable size for the experiment. Two aliquots were allowed to stand open in the laboratory; each of the others was placed in a wire basket above approximately one liter of sulphuric acid of known concentration in a desiccator and allowed to stand two weeks. The following acid concentrations were used: 25, 50, 75, and 95 per cent, designed to maintain relative humidities in the desiccators of roughly 85, 35, 5, and less than 1 per cent respectively.

At the end of the desiccation period, one of the aliquots previously standing open was divided into three parts, each of which was then placed in an open bottle. The remaining aliquots were divided into samples of approximately 500 seeds. Each sample was then immediately placed in a glass test tube, corked, and tightly sealed by dipping into a warm paraffin-beeswax mixture. The samples of all aliquots were then divided into three groups, one of which was placed in each of three constant temperature rooms maintained at 0, 10, and 20 degrees C., respectively.

At the beginning of the experiment and at successive intervals of 6 to 8 weeks, one sample from each aliquot at each temperature was removed from the temperature chamber, triplicate samples of

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100 seeds each counted out, and germination tests run. In all cases seeds were germinated at 20 degrees C. between moistened blotters in a germinator at the Minnesota State Seed Testing Laboratory. Counts of germinated seeds were made every second or third day over a period of two weeks.

RESULTS AND DISCUSSION

The viability test begun just after the desiccation period showed a fairly uniform germination of 65 to 70 per cent. Results of germination tests, given as the average percentage germination for the three replicates, are presented in the table below.

TABLE I—PERCENTAGE GERMINATION OF ELM SEED AFTER STORAGE AT DIFFERENT TEMPERATURES, AND WITH VARIOUS MOISTURE CONTENTS

	Oct. 9	Nov. 20	Jan. 8	Mar. 6	Apr. 26	July 9
A. Storage at 0°C.						
Open to air entire period . . .	46.33	39.67	53.00	53.33	6.00	0
Not desiccated, but sealed . . .	41.00	35.67	37.67	47.67	7.33	0
Desiccated over 25% acid . . .	39.33	23.33	54.67	51.67	11.33	3.00
Desiccated over 50% acid . . .	44.00	35.67	57.00	61.33	9.00	2.67
Desiccated over 75% acid . . .	48.33	35.67	53.00	47.67	12.00	3.67
Desiccated over 95% acid . . .	45.33	26.33	57.33	55.33	12.67	6.00
B. Storage at 10°C.						
Open to air entire period . . .	47.00	35.67	27.67	48.67	2.33	0
Not desiccated, but sealed . . .	42.67	21.67	35.67	42.00	3.33	0
Desiccated over 25% acid . . .	40.33	20.00	42.67	34.33	3.67	0
Desiccated over 50% acid . . .	40.33	32.33	42.67	56.67	10.33	3.33
Desiccated over 75% acid . . .	55.33	14.67	46.67	57.67	8.00	2.33
Desiccated over 95% acid . . .	41.33	53.00	46.67	64.00	10.67	3.33
C. Storage at 20° C.						
Open to air entire period . . .	34.33	29.67	18.67	6.33	0.00	0
Not desiccated, but sealed . . .	36.33	26.00	22.00	13.67	1.00	0
Desiccated over 25% acid . . .	41.00	28.33	11.50	1.67	.67	0
Desiccated over 50% acid . . .	42.00	27.67	51.33	38.33	3.67	2.00
Desiccated over 75% acid . . .	42.33	30.00	63.33	28.33	3.67	2.33
Desiccated over 95% acid . . .	41.67	33.00	32.67	44.00	6.33	1.67

The above results show some general tendencies which seem of importance in determining the optimum conditions for elm seed storage. Many of the elm seeds have a rest period through which they must pass regardless of storage conditions. This is evidenced by a gradual fall in germinating ability for a time, followed by a period of much higher germination. Length of the rest period appears to be influenced both by moisture content of seeds and by the storage temperature. In general, the data show that the rest period is somewhat shorter when storage is at 0 degrees C. than at 10 degrees C., regardless of moisture content. At 10 degrees C. this period appears to be a little longer, but it is not clear whether or not moisture content has influenced this lengthening. At 20 de-

degrees C., however, there is unmistakable evidence that the moisture content, as well as temperature, is responsible for the continuous falling off in seed viability and failure to recover from the dormant condition. It is possible that these factors may have prolonged the rest period in this case, but the exact extent cannot be shown since the continuous fall in viability masks the time of ending of the rest period. Where the seeds at 20 degrees C. were left open to air continuously, sealed in test tubes without desiccation or desiccated over 25 per cent sulphuric acid, the percentage germination fell off continuously from the beginning of the experiment. However, when the seeds were desiccated over 50, 75, or 95 per cent acid, they showed a poorer germination for a time, due to dormancy, followed by a much higher viability, then a final continuous loss in ability to germinate.

While it is impossible to state definitely the exact length of the rest period in the elm seed, the data suggests that it begins within a few weeks after harvest of seed and terminates approximately 6 months later. The period of high viability following the rest period appears to last about 3 months.

The germination data relating to storage indicate quite clearly that 0 degrees C. is a better temperature for storage than either 10 or 20 degrees C., and that 10 degrees C. is much to be preferred to the 20 degrees C. temperature, particularly if seeds cannot be sufficiently desiccated.

In regard to moisture content, it appears from this experiment that the more the seeds are desiccated, the higher is the percentage of germination at any time and the longer viability is retained.

No attempt is made to state definitely the optimum conditions for elm seed storage, but vitality is best retained at relatively low temperatures and with very low water content in the seed.

A Study of the Broad-leaf Evergreens of the Southeastern States

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THE region covered by this study includes the states east of the Mississippi River and south of the Potomac and Ohio Rivers, except the central and southern parts of Florida, the limit in Florida being defined by an imaginary line between St. Augustine, Palatka, Gainesville, then due west to the Coast.

The materials studied include both native and introduced broad-leaf evergreens which are used in cultivation and show promise of use for landscape purposes, over 500 in all. A preliminary study of herbarium specimens was made during the spring and summer of 1930 at the New York Botanical Garden, and of Dr. L. H. Bailey's collection in Ithaca, New York.

During the latter part of December 1930, and January and the first part of February 1931, a trip was made through the southeastern states for the purpose of observing these ornamentals in their native habitat and more especially to consider their actual use for landscape purposes, and to observe the climatic and soil conditions in which these materials occur. Visits to the more important nurseries, estates, plantations, gardens, state institutions, parks, and cemeteries afforded an opportunity to gather first hand information relative to the material under actual growing conditions. Consultations were held, and advice and suggestions were obtained from prominent nurserymen, landscape architects, estate owners, gardeners, and university professors.

During June and July 1931, a second trip was made to make further observations, collect specimens, and gather data by stopping at a selected number of places and through consultation with well-informed men with whom previous contacts had been made. These two expeditions gave opportunities to study the broad-leaf evergreens in both winter and summer. The collected specimens were taken to the Arnold Arboretum for verification of the correct names by Dr. Alfred Rehder and also were determined by Dr. L. H. Bailey.

On these trips it was found that several plants, through error, are being sold under incorrect names. A common practice by some of the nurserymen is the application of local pseudo-scientific names for species, variety, and forms.

One of the most important results of this study is the preparation of a plant character table which shows the scientific names according to the international rules of botanical nomenclature which are followed in Bailey's "Hortus", and Rehder's "Manual of Cultivated Trees and Shrubs," and the common names according to "Standardized Plant Names." Separate columns show (a) resistance to drought, (b) rate of growth, (c) form, (d) size, (e) foliage, including texture, and color in fall and winter, (f) flowers, includ-

ing date, duration, fragrance, and interesting combinations, (g) fruits, including date, season, color, and whether edible by birds or by man, (h) soil conditions, including type, acidity, and moisture, (i) light requirement including sun, half-shade, and full-shade, (j) range, whether mountain, Piedmont, or coastal plain and the northern and southern limits in each region, (k) landscape uses, (l) propagation, and (m) general remarks.

The generally moderate climate and the wealth of plant materials, particularly the broad-leaf evergreens, available for ornamental use in the southeastern states, should make easy the development of a beautiful all-year-round landscape effect with an everblooming and attractive garden.

One of the first points to consider in planning and planting these materials in the southern states, is that the growing season in the region is many times longer than in latitudes further north. Almost as much growth may be obtained in one season in the general region under consideration as can be secured in the northeastern states in two or three years. This is, of course, not true of the higher elevations which more or less approach northern conditions. At present there seems to be a shortage in the number of low, compact shrubs to be used for planting, as "facer" material, around the base of taller growing plants. A very common mistake is the use of several plants in an area of restricted dimensions, thus producing an overplanted situation, where one specimen is adequate to produce the desired effect and fill the allotted space. This is due directly to a lack of knowledge regarding the habits and characteristics of these materials.

The climatic and soil conditions vary greatly and the plant materials suited to the region are different from many of those of other localities. Many plants suited to more northerly regions are not suited to the southeastern states. It is common for persons who plant gardens in a region with which they are not familiar to use plants with which they have been associated. They fail to consider the suitability of the plants to the new climatic and soil conditions. For example, plants such as *Taxus cuspidata*, *Tsuga canadensis*, *Pinus strobus*, and many others which are well suited to the northeastern states but not typical of the south, have been and are being planted in many localities in the southern states. These usually become unhealthy and soon meet with failure in this situation. It is true that there are certain localities in the region under consideration where these plants are desirable. The fine introduced material proven to be perfectly hardy and happy and the abundance of native plants which the region offers have been too often neglected.

The deciduous material of the north is excellent for the north where there is not such a wide range of broad-leaf evergreens, but in the south where such splendid broad-leaf materials are available, these certainly should be favored. After the evergreen effect is produced, the residents of the south want color in the landscape. This

can be secured by flowers and bright-colored fruits, which are very desirable during the fall and winter months. More attention should be given to the propagation and use of berry-bearing evergreen plants. Because these plants are evergreen and, as a group, are naturally restful and informal, they seem to fit readily into the landscape.

In addition to the plant character table, this study of the broad-leaf evergreens will provide charts, lists, description and discussion on 30 different topics of which the following are typical, namely, new introductions and native materials which are little known; fragrant flowers and attractive fruits; the blossom circle of the year among the broad-leaf evergreens; plants for hedges, topiary work, wind-breaks, and borders; the old stand-bys and the 20 favorites; broad-leaf evergreens for near the seashore; southern broad-leaf evergreens which may be useful in the north; and several special groups, such as azaleas, rhododendrons and other ericaceous plants, box and its place in the southern garden, the camellias, the *elaagnus* and *euonymus*, the hollies and *osmanthus*, the honeysuckles, privets, and *viburnums*, the palms and *yuccas*.

Very little is published which deals with the much needed information on the cultivated broad-leaf evergreens. It, therefore, is the aim of the present study, to prevent further mistakes by furnishing up-to-date, practical and dependable information on these materials.

Rooting Response of Conifers to Treatments with Organic and Inorganic Compounds

By IRWIN KLEIN, *Ohio State University, Columbus, Ohio.*

SEVERAL investigators, including Hitchcock and Zimmerman (1) and Chadwick (2), studied the effect of rooting cuttings at various periods during the year. A comparison of results showed variations, particularly between November and March, which the writer thought might be due to either an unbalanced nutritive condition or a slow physiological activity. This supposition was confirmed by considering reports of other investigators. Starring (3), Reid (4), and others observed that cuttings high in carbohydrates and low in nitrogen rooted well, while those with a reverse ratio rooted poorly. Curtis (5), Zimmerman (6), Skinner and Reid (7), found that oxidation reactions markedly increased root activity. All these facts suggested that treatments with organic or oxidizing reagents might increase the rooting of evergreens.

Five kinds of plants, *Thuja occidentalis*, *Chamaecyparis pisifera plumosa*, *Juniperus sabina*, *Juniperus chinensis pfitzeriana*, and *Taxus cuspidata*, were selected for the experiment. Cuttings were prepared on approximately the 25th of each month from November to March inclusive. Twenty-five cuttings were used in each test, a total of 1250 each month for the 10 treatments, consisting of three organic compounds, namely, sucrose, glucose, and glycerine of 5 per cent and 10 per cent concentrations, and three inorganic substances, namely, potassium permanganate, manganese sulphate, and hydrogen peroxide, of .01M, .0001M, and .05M respectively, and one check plot. The cuttings were placed in these solutions for 24 hours, rinsed with water, and inserted in sand of neutral reaction. Frequent determinations showed that acidity remained fairly constant throughout the experiment. On June 30, 1931, all the cuttings were lifted and records taken. The unrooted were reinserted into the propagating medium where they remained until July 22. At this time final measurements were recorded.

A separate study of each genus indicates the results.

Thuja occidentalis: The December treated cuttings were by far the best. As many as 96 per cent rooted in this lot under the potassium permanganate treatment. The next best inorganic chemical was hydrogen peroxide. The test with 10 per cent glycerine produced the poorest results. The lowest per cent of rooting was recorded in the March cuttings. The number and the length of the roots was greatest with the December cuttings treated with potassium permanganate or 5 per cent sucrose.

Chamaecyparis pisifera plumosa: This genus rooted poorly in every lot. The drought of the 1930 season, undoubtedly, affected the condition of the terminal growth, resulting in poor cuttings. The highest

percentage of rooting was recorded in the November and the December tests with the potassium permanganate treatment.

Juniperus sabina: The cuttings of this genus rooted better than any of the other materials used in the experiment. A 10 per cent glucose solution used in the November lot yielded the highest percentage of rooted cuttings, although for an average of the 5 months, potassium permanganate took the lead. Next to potassium permanganate, the treatments with 5 per cent sucrose and manganese sulphate were most satisfactory.

Juniperus chinensis pfitzeriana: Most of the cuttings rooted poorly, although they had callused. Again potassium permanganate, followed by 5 per cent sucrose, produced the best results.

Taxus cuspidata: Because of the scarcity of material only three lots, November, January, and February, were used. All cuttings rooted well, although the November and December lots were best. Potassium permanganate, followed by 5 per cent glucose and 10 per cent glycerine, yielded the highest percentage rooting.

In all cases potassium permanganate produced the best results. In several lots the organic treatments were close seconds, as Table I shows. Cuttings taken during late fall, November and December, rooted better than later lots. Since most of the evergreens complete their rest period by the middle of November or early December, cuttings taken at this time are more apt to react favorably to stimulation.

In this experiment organic compounds produced most of the early stimulation, although over a longer period (see Table II) potassium permanganate was best. From Table III the results indicate that potassium permanganate and sugar solutions were effective equally in stimulating the number and length of the roots. However, with three genera the cuttings in the check lots produced roots as long as the treated ones. Curtis attributes the stimulative power of the potassium permanganate to the release of oxygen as it comes in contact with the plant tissues. The liberation of oxygen, probably, affects respiration and causes more complete oxidation.

When cuttings were removed from the potassium permanganate solution a black-purplish precipitate, manganese dioxide, adhered to the wood. Bunnell and Hasselbring (8) point out that in some cases a straw-colored solution containing manganese and giving strong oxidase reactions may accompany the chemical change. Furthermore, this substance is useful as a disinfectant and as such it may help to check the growth of micro-organisms in or about the tissues of the cutting.

Other investigators associated manganese with the oxidation reactions occurring in plants. Many state that the oxidizing enzymes act more powerfully in the presence of manganese compounds. Possibly one of the most plausible explanations advanced for the stimulus of growth by manganese was offered by Loew (9). He compares the action of manganese with the effect of light. Although light aids the

TABLE I—CHEMICAL STIMULATION OF EVERGREEN CUTTINGS
(Recorded June 30, 1931)

Treatment	Best Single Lot		Average Results			
	Month	Chemical	Best	Poorest	Best Month	Poorest Month
<i>Thuja occidentalis</i>	Dec.	KMnO ₄	KMnO ₄	10% glycerine	Dec.	March
<i>Chamaecyparis pisifera plumosa</i>	Nov.	10% glycerine	KMnO ₄	10% sucrose H ₂ O ₂	Nov.	March
<i>Juniperus sabina</i>	Nov.	10% glucose	KMnO ₄	10% glycerine	Nov.	March
<i>Juniperus chinensis pfitzeriana</i>	Dec. and Feb.	10% sucrose and 5% glucose	10% sucrose and 5% glucose	5% glycerine 10% glycerine	Feb.	March
<i>Taxus cuspidata</i>	Dec.	5% sucrose	5% sucrose	5% glycerine	Dec. Nov.	Feb.

TABLE II—FINAL RESULTS OF CHEMICAL STIMULATION OF EVERGREEN CUTTINGS
(Recorded July 25, 1931)

	<i>Thuja occidentalis</i>	<i>Chamaecyparis pisifera plumosa</i>	<i>Juniperus sabina</i>	<i>Juniperus chinensis pfitzeriana</i>	<i>Taxus cuspidata</i>
Treatment producing highest per cent root- ing	KMnO ₄	5% glycerine 10% glycerine KMnO ₄	KMnO ₄	KMnO ₄ H ₂ O ₂	KMnO ₄
Second best treatment	H ₂ O ₂	5% sucrose MnSO ₄	5% sucrose MnSO ₄	5% glucose	5% glucose 10% glycerine

TABLE III—CHEMICAL TREATMENTS WHICH PRODUCED THE GREATEST NUMBER AND ROOT LENGTH OF THE EVERGREEN CUTTINGS

	Greatest Number of Roots		Greatest Root Length	
	Chemical	Month	Chemical	Month
<i>Thuja occidentalis</i> ..	KMnO ₄ 5% sucrose	December	KMnO ₄ 5% sucrose	December
<i>Chamaecyparis pisi- fera plumosa</i>	10% glucose	December	Check 10% glucose	November
<i>Juniperus sabina</i> ...	KMnO ₄ 10% sucrose	November January	Check 5% glucose	November
<i>Juniperus chinensis pfitzeriana</i>	KMnO ₄ H ₂ O ₂	December	KMnO ₄	December
<i>Taxus cuspidata</i> ...	KMnO ₄	December	Check	December

increase of food manufacture, through photosynthesis, it prevents its utilization. Only in the absence of light does any appreciable amount of growth occur. The absence of light has the same effect as the presence of manganese, which tends to increase growth throughout the day. The check in growth during the day may be due to the action of certain noxious compounds produced in the cells under the influence of light. It is known that oxidizing enzymes destroy these toxic by-products. Consequently, since manganese increases the oxidizing power of the enzymes the noxious compounds are broken down as rapidly as they are formed, allowing growth functions to continue unmolested.

Wherever hydrogen peroxide was effective, the stimulation was due to the increased oxidation, undoubtedly, since it liberates free oxygen readily in water.

The direct absorption of organic compounds, namely the sugars, produced varying results, in the evergreen cuttings; however, with softwood and succulent material their importance was pronounced. Cool weather of fall causes an accumulation of sugars within the plant. With the normal breaking of the rest period, the stored food is consumed gradually in the formation of roots and top, so that sugars are seldom a limiting factor. The small amount of stimulation produced with the organic treatments was due, possibly, to the soluble condition of the sugar which was assimilated quickly by the plant. The importance of organic compound treatments is governed largely by the maturity of the wood; immature cuttings show greater stimulation than mature twigs.

Although potassium permanganate and sugar compounds were the two most outstanding treatments in this experiment, there is still some doubt as to whether they are of any commercial value to the nurseryman.

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Studies in Propagation of Softwood Cuttings of Ornamentals Based on Temperature, Defoliation and Kind of Media

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EXPERIMENTAL work during the past few years has shown that materials other than sand deserve consideration as media for the vegetative propagation of plants by cuttings. Peat and combinations of peat and sand, as well as slag and combinations of slag and peat, or slag and sand, may be superior to sand as propagating media.

The ideal bottom heat in stimulating rooting has been given little attention. If a difference of 8 or 10 degrees in temperature is as effective in stimulating or retarding root action as it is in top growth relations, there is need of more research in this direction.

The effect of defoliation has been a matter of contention and little work has been done to check the effect of leaf removal partial or whole, against the retention of the full leaf surface on cuttings.

With these three factors in mind, a series of investigations concerning the rooting of cuttings of ornamentals was started at Ohio State University in the winter of 1930-31.

EFFECT OF BOTTOM HEAT

In the University greenhouse in which the experiments were conducted, hot water heats the propagating bench. Four pipes extending the length of the bench can be regulated to supply a given flow. The temperature thus maintained averages about 60 degrees F.

During the winter, an Electromaster Heating Unit, manufactured by Electromaster, Inc., of Detroit, was used. Each unit is 33 by 33 inches, approximating 9 square feet of space. The Electromaster electric heater has an adjustable thermostat which can be regulated to afford temperatures of from 55 to 90 degrees F.

The heating unit was installed directly below the bench and was completely closed on the bottom and sides so that the greater portion of the heat would go up into the propagating bench. The propagating bed was filled with 8 inches of sterilized sand, and the thermostat of the heating unit was so regulated that a temperature of 70 degrees F. was maintained in the medium, which was 10 degrees higher than that maintained in the check propagating bed.

Cuttings were inserted on January 28, 1931, in both the check plot and the one with additional heat, of *Coleus blumei*; *Chrysanthemums* Silver Sheen, Gladys Pearson, Golden Glory, Garza and Alice; *Antirrhinum majus*; *Hedera helix*; *Pelargonium hortorum*; *Dianthus*, White Matchless; *Centaurea cineraria*; *Heliotropium peruvianum*; *Felicia anelloides*; *Begonia melior*; *Plumbago campensis*; *Mathiola incana*; *Pandanus vitchi*; *Acalypha tricolor*; *Allamanda thomsonae*;

Sansevieria zylandica; *Clerodendron thomsonae*; *Achyranthes brilliantissima*; *Stevia serrata*; *Santolina incana*; *Buddleia davidi*; *Fuschia hybrida*; *Petunia hybrida*; and *Lantana camara*.

In all cases except *Santolina incana*, the time required for rooting cuttings was reduced with a temperature of 70 degrees F. During late winter cuttings in the check plot required from 4 to 16 days longer to attain the same degree of rooting as secured at 70 degrees F. During the early spring, with more sunny days there was commonly a difference of 3 to 4 days or more.

Usually the rooting percentage was in favor of the plot at 70 degrees F., but during the warm sunny days of spring in three cases a higher rooting percentage was secured with the check plot. With sunshine, maintaining a uniform temperature of 70 degrees F. becomes a more complicated problem with the Electromaster heating unit.

These results indicate that a temperature of 70 degrees F. is more suitable for rooting most species than a temperature of 60 degrees F. With other species, like *Pandanus veitchi*, it is a necessity.

EFFECTS OF DEFOLIATION

During the middle of January, 1931, a preliminary experiment was begun to find the effects of defoliation on the rooting of cuttings. Cuttings were made up in four ways when sufficient material was at hand, namely, (1) all leaves removed, (2) half of the leaves removed, (3) half of the leaves removed and remaining leaves trimmed, and (4) no leaves removed. Cuttings were then inserted in a sand medium in the usual manner.

A slightly different procedure was used during the following spring, the cuttings being made up with (1) all leaves trimmed to reduce the leaf area approximately one-half; (2) half the lower leaves removed, and (3) no leaves removed. Approximately the same amount of leaf surface was allowed in cases (1) and (2) above, and an attempt to approximate the usual defoliation was made.

Species of plants used in the defoliation experiments were *Chrysanthemums*, Mistletoe, Silver Sheen, and Gladys Pearson; *Antirrhinum majus*; *Fuschia hybrida*, Black Prince, Trophee, Indianola, and Double White; *Dianthus caryophyllus*, Morning Glow and White Matchless; *Vinca major*, *Begonia semperflorens luminosa*, *Coleus blumei*, *Heliotropium peruvianum*, *Pelargonium hortorum*, *Santolina incana*, *Achyranthes brilliantissima*, and *Hydrangea hortensis*.

In practically all cases as high or higher rooting percentages were secured with defoliated cuttings. However, the number and length of roots per cutting was encouraged by the additional leaf surface exposed. Complete defoliation, as might be expected, gave poor results.

These experiments, though not conclusive, indicate that in making cuttings of many varieties of plants, root development and growth is in proportion to the leaf surface exposed. In several cases, as with

Achyranthes brilliantissima and *Chrysanthemum*, undefoliated cuttings grew at least one-third taller in the bench. It would seem that the size of leaf of the plant should be the governing factor in defoliation. If the leaf area is large, as with *Hydrangea hortensis* or *Coleus blumei*, it should be somewhat reduced. If the leaf area exposed is small, as with *Santolina incana*, or *Dianthus caryophyllus*, defoliation has but little effect. With most plants having medium-sized leaves, where root development is promoted, it would seem best not to practice defoliation, at least not on the scale in common practice.

EFFECT OF MEDIA

During the fall and winter of 1930-31 tests of rooting in various media were made. Slag, sand, peat, equal mixtures of peat and sand, and peat and slag were tried. Nine species of plants were tried in these media, namely, *Crassula arborescens*; *Begonia melior*; *Heliotropium peruvianum*; *Pelargonium graveolens*; *Santolina incana*; *Echeveria secunda glauca*; *Dianthus*, White Matchless; *Vinca major*; and *Stevia serrata*.

Begonia melior and *Dianthus*, White Matchless, showed highest percentage rooting in pure slag; *Heliotropium peruvianum* rooted best in the mixture of peat and sand; *Echeveria secunda glauca* and *Vinca major* rooted best in pure sand; *Santolina incana* and *Stevia serrata* gave best results in the mixture of peat and slag. *Crassula arborescens* gave perfect rooting percentages in the mixture of peat and sand, in peat and slag, and in pure sand, and *Pelargonium graveolens* rooted 100 per cent in both pure slag and pure peat, media very unlike in all respects.

Slag when used as a medium by itself produced from fairly well rooted to well rooted plants in the different species. Since slag alone is not very retentive of moisture, slag and peat together form a very desirable medium, for root stimulation and root growth. Peat, being very retentive of moisture and containing some little nourishment, when combined with slag, should make a good combination for many plants. Since slag is decidedly basic, testing well over over pH 8, while peat is acid (pH 4), a slightly acid medium is secured when the two media are combined. With peat, plants seem to fall into either one of two classes, *i.e.*, rooting either exceptionally well with long and well developed root systems, or very poorly.

Results given here indicate that sand is not the best propagating medium for all plants. The combinations of peat and slag, and peat and sand are particularly valuable.

Factors Influencing the Rooting of Deciduous Hardwood Cuttings

By L. C. CHADWICK, *Ohio State University, Columbus, Ohio.*

DURING the past few years considerable experimental work on factors influencing the rooting of cuttings has been published. Much of this has dealt with deciduous softwood cuttings, with less attention given to evergreens. The little work reported with deciduous hardwood cuttings has dealt mostly with tests to determine their immediate rooting ability when taken at different periods of the year and handled in different media. Little work of importance has been done on the storage factors and their relation to the subsequent rooting ability of the cuttings.

A large number of ornamental plants are propagated by hardwood cuttings. As ordinarily handled by commercial nurserymen the wood is gathered in late fall after a few hard freezes have occurred and the cuttings are made into lengths of 7 to 9 inches and stored in bunches of 25 to 50. Very little attention is given to either the top or basal cut. The cuttings are stored in various positions in boxes of moist sand that are kept in cool places, such as storage cellars, or buried in sandy knolls outside, until the following spring, when they are lined out in nursery rows. This empirical practice with its many minor variations has been handed down to us from early gardeners and has little scientific background.

As a preliminary study the following factors were considered: the influence of (1) the time of taking, (2) storage media, (3) the position of the basal cut, and (4) storage temperature, on the subsequent rooting of the cuttings.

Cuttings were taken and stored as indicated in the various tests. All cuttings were lined out in early April in a clay loam soil under an overhead irrigation system. The data were recorded in late May, after considerable growth had taken place. Since hardwood cuttings frequently send out shoot growth soon after planting, but roots fail to develop and they die, only those cuttings showing vigorous top growth were counted as rooted.

Cuttings were taken each month from November to April. Sets were made with the basal cut (1) $\frac{1}{2}$ inch above the node, (2) at the

TABLE I—THE INFLUENCE OF THE TIME OF TAKING ON THE ROOTING OF HARDWOOD CUTTINGS
(Percentage Rooted)

Plant	Month of Taking					
	November	December	January	February	March	April ¹
<i>Cornus alba</i>	62	64	76	78	66	68
<i>Ligustrum vulgare</i> ..	0	8	86	70	98	100
<i>Lonicera morrowi</i> ..	48	54	76	92	98	68

¹Cuttings were taken, made, and lined out directly in the nursery row.

node, and (3) $\frac{1}{2}$ inch below the node. Storage was in sand, a mixture of equal parts by volume of sand and peat, and in peat. To present the data clearly and concisely it has been summarized on the unit basis of 50 cuttings.

The data in Table I show clearly that late winter and early spring is a better time to take cuttings than late fall and early winter. The variation with *Cornus alba*, though not great, was consistent.

TABLE II—THE INFLUENCE OF DIFFERENT STORAGE MEDIA ON THE ROOTING OF HARDWOOD CUTTINGS

Plant	Medium	Month of Taking				
		November	December	January	February	March
<i>Cornus alba</i> . . .	Sand	38	56	76	70	58
	Sand and Peat	62	64	60	78	66
	Peat	28	44	50	42	52
<i>Ligustrum vul-gare</i>	Sand	0	8	86	56	90
	Sand and Peat	0	2	52	70	98
	Peat	0	0	52	56	90
<i>Lonicera mor-rowi</i>	Sand	48	54	76	82	96
	Sand and Peat	24	38	66	92	98
	Peat	24	12	54	82	82

From the data given in Table II it would seem that there is little difference between sand and the mixture of sand and peat moss. Considering the months in which the cuttings rooted best the mixture of sand and peat has a slight advantage. The shorter the storage period the better were the results received with peat moss.

TABLE III—THE INFLUENCE OF THE POSITION OF THE BASAL CUT IN RELATION TO THE NODE ON THE ROOTING OF HARDWOOD CUTTINGS
(Percentage Rooted)

Plant	Position of Basal Cut	Month of Taking					
		November	December	January	February	March	April ¹
<i>Cornus alba</i> . . .	Above	44	50	54	74	58	56
	At	54	56	65	56	66	64
	Below	40	50	74	74	60	72
<i>Ligustrum vul-gare</i>	Above	0	2	70	60	98	100
	At	0	0	64	68	88	100
	Below	0	8	72	54	92	96
<i>Lonicera mor-rowi</i>	Above	30	28	56	82	92	52
	At	20	38	66	86	94	84
	Below	42	40	72	90	96	36

¹Cuttings were taken, made, and lined out directly in the nursery row.

The data recorded in Table III show that a basal cut $\frac{1}{2}$ inch below the node was slightly superior to the others. The cut at the node proved as good in nearly as many cases. The one above the node seems inferior except with *Ligustrum vulgare*.

A test was started in the fall of 1930 to study the influence of different temperatures on the storage of hardwood cuttings. The cuttings were handled as indicated in the headings in Table IV.

TABLE IV—THE INFLUENCE OF STORAGE TEMPERATURES ON THE ROOTING OF HARDWOOD CUTTINGS

Plant	Percentage Rooted ¹				
	Taken and Lined Out in Nov.	Stored Continuously at 40°F.	Stored 2 Wks. at 60°F., then at 40°F.	Stored at 40°F Except Last 2 Wks. at 60°F.	Taken and Lined Out in April
<i>Cornus alba</i>	20	60	80	48	72
<i>Hibiscus syriacus</i>	20	64	56	28	8
<i>Lonicera morrowi</i>	84	36	76	20	84
<i>Ligustrum vulgare</i>	88	—	—	—	100

¹50 cuttings used as the unit.

The data recorded in Table IV indicate that a high temperature for a period of 2 weeks at the start of the storage period is beneficial. Cuttings taken in the fall and in the spring and lined out directly gave better results than expected, but there was considerable variation among the different plants.

DISCUSSION

The accepted practice in taking cuttings (1) is in autumn or early winter before heavy freezing has occurred. The data recorded here-with indicate better results occur when they are taken late in winter or early spring. A possible explanation for this fact is that the shorter the time the cuttings are in the storage medium the less is the chance of their drying out, while bacterial and fungus infections may also be avoided. Several investigators (5, 9, 4), have shown that there is considerable change in the nature of the food supply during the winter months. The food supply influences the formation of root initials and healing tissues. It is possible that the change in the food supply is more favorable when the cutting wood is attached to the plant in its normal condition than when stored as detached individuals in some storage medium.

The advantages of taking cuttings late in the winter, other than the increased percentage of rooting, are that there is more time for such work and less attention required because of shorter storage period. Except for the rush of the spring season it would seem advisable to take cuttings and line them out directly, if results could be obtained similar to those secured in this test.

The disadvantage of taking cuttings in late winter lies in the danger of obtaining frozen or partly weakened wood. One important fact derived from this test is that the propagator need not limit himself to a short period in taking his hardwood cuttings.

The advantages of peat in the rooting medium for softwood cuttings have been definitely proved, (2, 8). Its influence in the storage

medium for hardwood cuttings seems less important but it is effective in many cases. The effectiveness of the peat moss probably lies in the fact that fluctuations in moisture and temperature content are somewhat less, together with increased acidity. It is difficult to maintain a sufficiently low moisture content in peat to make it a satisfactory storage medium. This is especially true if the cuttings are stored for considerable time. With the shorter storage periods peat of low or medium moisture content makes an ideal medium.

The superiority of the basal cut made below the node has been clearly shown by Chadwick (3) working with softwood deciduous cuttings. The various reasons given for this reaction do not need discussion here. The position of the cut seems less important with hardwood cuttings. This is due in part to the difference in anatomical nature of soft- and hardwood cuttings. Other conditions for rooting being satisfactory, it would seem that the position of the basal cut will not influence the process enough to make it advisable for the commercial propagator to make the cut in some exact position on such cuttings.

The explanation of the fact that a high temperature for a period of 2 weeks at the start of the storage period is beneficial probably lies in the nature of the root and shoot development of cuttings taken in the fall. Since rest in plants is localized in the buds, as has been definitely proved by various investigators, (5, 6, 7), the explanation of the reaction of hardwood cuttings to the temperature change seems apparent. Buds on cuttings taken in November are in a resting condition but since the root initials and meristematic tissues at the base of the cutting have no resting stage, the high temperature at the start of the storage period enables callus and root initial development to proceed at a more rapid rate than would occur at the lower storage temperature. Thus at the time the temperature is lowered the basal cut is well healed over by a protective, suberized layer, if not by a callus, and undoubtedly considerable root initial development has occurred. The 40 degrees F. throughout the winter is sufficient to hold the root development in check and at the same time to break the rest period of the buds. Very little, if any, shoot development, however, takes place at this temperature. When the cuttings are lined out in the spring the roots and shoots are ready for simultaneous development, which is the desired condition.

Storage at a continuous low temperature (40 degrees F.) usually gives good results, but at this temperature the basal wound is often not properly healed and root initial development is checked. This condition may result in basal decay and a slow root development in the spring that frequently results in death of the cutting.

The storage period ending with a 2-week period at 60 degrees F. does not seem favorable. This is probably due to the fact that the high temperature aids a pre-season shoot development, using the food in the cutting at the expense of root development.

The practice of lining out cuttings in the fall proved successful

with *Ligustrum vulgare* and *Lonicera morrowi*. This should become commercially practical with the hardiest types of cuttings and where a sandy field is available for the lining out area. In heavy soils considerable heaving is apt to occur unless mulching is practiced. Cuttings taken in early spring and lined out at once frequently do not give good results because shoot growth takes place previous to root development. With those types of cuttings that are rather slow in breaking buds in the spring this method of handling may be feasible.

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Experiences in Rooting Soft and Hardwood Cuttings of Hardy Fruits

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THE difficulties experienced in the rooting of cuttings of the hardy fruits have been recorded by many workers. The data in this paper are presented in order to place on record still another set of conditions for the same general problem, the work being done at Geneva, N. Y.

SOFTWOOD CUTTINGS OF APPLE, CHERRY, PEAR, AND PLUM

Softwood cuttings were made at three dates in mid-summer with two varieties of apple (*Pyrus malus*), two of sweet cherry (*Prunus avium*), two of plum (*Prunus domestica* and *P. cerasifera*), and one of pear (*Pyrus communis*), using wood from bearing trees in the varietal orchard. They were struck in bank sand, in granulated peat moss, and in equal parts of each, in both an outdoor hotbed and in the greenhouse with additional window sash cover.

The results are shown in Table I, where it is seen that from 1,080 softwood apple cuttings of two varieties, struck at three dates in mid-summer, in three different rooting media, and in two locations, not one rooted plant was obtained. Of the cherries, one rooted cutting was secured from a like number under a similar set of conditions; while with pears only one cutting rooted from 720 made. Although the rooting of Italian Prune (*Prunus domestica*) was negative, a small number of De Caradeuc (*Prunus cerasifera*) cuttings were successful and developed into strong plants. It is interesting to note that *P. cerasifera* is one of the parents of the Marianna plum, used as an understock for plums, and propagated regularly from cuttings in the Southwest. The most successful medium for rooting was the peat-and-sand mixture, with peat alone next.

It is also interesting to note that on March 28, after 9 months in the propagation frames, these softwood cuttings were still alive and calloused, some of the pear cuttings were still alive, most of the cherry cuttings were dead, all of the Italian Prune (*Prunus domestica*) cuttings were dead, and many of the DeCaradeuc (*Prunus cerasifera*) cuttings were still alive. All of the rooted cuttings developed into vigorous plants.

HARDWOOD CUTTINGS OF APPLE VARIETIES

Hardwood cuttings were made of five varieties of cultivated apple (*Pyrus malus*) and of *Malus baccata*, struck in equal parts of peat and sand in late winter in the greenhouse, using cuttings of both 1-year-old wood, and also 1-year-old wood plus portions of 2- and 3-year-old wood. Cuttings were made from bearing trees. From this lot of hardwood cuttings only one cutting was rooted, as seen in Table II, namely, a cutting carrying part 2- and part 3-year-old wood.

TABLE I—ROOTING OF SOFTWOOD CUTTINGS (1930)

	Date Made	No. Cuttings	Medium Used for rooting			Place of Propagation	Number rooted in		
			Medium Used for rooting				Sand	Peat & Sand	Peat
			Sand	Peat & Sand	Peat				
Apple ¹									
Northern Spy.....	June 16	180	60	60	60	Greenhouse	None	None	None
Northern Spy.....	June 16	180	60	60	60	Hotbed	None	None	None
Northern Spy.....	July 18	180	60	60	60	Greenhouse	None	None	None
Northern Spy.....	July 18	180	60	60	60	Hotbed	None	None	None
French Crab.....	July 6	180	60	60	60	Greenhouse	None	None	None
French Crab.....	July 6	180	60	60	60	Hotbed	None	None	None
		1080	360	360	360		None	None	None
Cherry ²									
Lyons.....	June 16	180	60	60	60	Greenhouse	None	None	None
Lyons.....	June 16	180	60	60	60	Hotbed	None	None	None
Lyons.....	July 18	180	60	60	60	Greenhouse	None	None	None
Lyons.....	July 18	180	60	60	60	Hotbed	None	None	None
Mazzard.....	July 6	180	60	60	60	Greenhouse	None	None	None
Mazzard.....	July 6	180	60	60	60	Hotbed	None	1	None
		1080	360	360	360		None	1	None
Pear ³									
Seckel.....	June 16	180	60	60	60	Greenhouse	None	None	None
Seckel.....	June 16	180	60	60	60	Hotbed	None	1	None
Seckel.....	July 18	180	60	60	60	Greenhouse	None	None	None
Seckel.....	July 18	60	60	60	60	Hotbed	None	None	None
		720	240	240	240		None	1	None
Plums ⁴									
Italian Prune.....	June 16	180	60	60	60	Greenhouse	None	None	None
Italian Prune.....	June 16	180	60	60	60	Hotbed	None	None	None
Italian Prune.....	July 18	180	60	60	60	Greenhouse	None	None	None
Italian Prune.....	July 18	180	60	60	60	Hotbed	None	None	None
De Caradenc.....	July 6	180	60	60	60	Greenhouse	None	6	1
De Caradenc.....	July 6	180	60	60	60	Hotbed	None	7	2
		1080	360	360	360		None	13	3

¹March 28: Some cuttings in sand and peat, and in peat calloused and still alive.²March 28: Some cuttings in peat and sand, and in peat still alive.³March 28: All Italian Prune cuttings dead. Some De Caradenc alive.⁴March 28: Most cuttings dead.

TABLE II—ROOTING OF HARDWOOD CUTTINGS OF CULTIVATED APPLES STRUCK IN GREENHOUSE IN EQUAL PARTS OF PEAT AND SAND, ON FEBRUARY 20, 1930

	No. Cuttings	Wood Used		Number Rooted	
		1-Year Wood	2- and 3- Yr. Wood	1-year Wood	2- and 3- Yr. Wood
<i>Malus baccata</i>	20	10	10	0	1
Northern Spy.....	20	10	10	0	0
Rome.....	20	10	10	0	0
Ben Davis.....	20	10	10	0	0
Whitney.....	20	10	10	0	0
McIntosh.....	20	10	10	0	0
	120	60	60	0	1

HARDWOOD CUTTINGS FROM LAYERED APPLE PLANTS

Hardwood cuttings were made from strains of vegetatively propagated apples during the seasons of 1930 and 1931. The material used comprised the unrooted shoots from layered plants, some with portions of 2-year wood attached, and some without. In addition cuttings were made from both tips and bases of 1-year wood. Table III shows the greatest success to have been obtained in the season of 1930, in general with cuttings carrying a portion of older wood. No rooted cuttings were secured from either tips or bases of

TABLE III—ROOTING OF HARDWOOD CUTTINGS OF LAYERED APPLE STOCKS, STRUCK IN FIELD ON MAY 21, 1930, FROM CUTTINGS MADE IN MARCH, 1930

	No. Cuttings	Wood Used			Per cent Rooted		
		1-Yr. Tips	1-Yr. Bases	2-Yr. Wood	1-Yr. Tips	1-Yr. Bases	2-Yr. Wood
Malling Type I (English Broadleaf Paradise).....	170	40	100	30	0.0	0.0	56.5
Malling Type IX (Jaune de Metz).....	65	—	25	40	0.0	0.0	57.5
Malling Type XII.....	50	—	20	30	0.0	0.0	0.0
Malling Type XIII.....	290	50	200	40	0.0	0.0	7.5
	575	90	345	140	—	—	—

1-year wood, whereas 56.5 per cent of Malling Type I (Broadleaf English Paradise) and 57.5 per cent from Malling Type IX (Jaune de Metz) were rooted in the case where heel cuttings of 2-year wood were used. On the other hand, only 7.5 per cent were secured from Malling Type XIII, and none from Malling Type XII.

For the season of 1931, Table IV shows the same relative rooting ability of the various types of stocks used, in which Types I and IX rooted best, and Type XIII rooted poorly. French Doucin rooted well, especially on 1-year wood. By contrast with the season of 1930, some rooting of 1-year wood was experienced for all types used excepting Type IX, although in general the heel cuttings of 2-year wood were again more successful.

TABLE IV—ROOTING OF HARDWOOD CUTTINGS OF LAYERED APPLE STOCKS STRUCK IN FIELD APRIL 24, 1931. (DUG NOVEMBER 24, 1931)

Material	Wood Used		Per cent Rooted	
	1-Yr. Wood	2-Yr. Wood	1-Yr. Wood	2-Yr. Wood
Malling Type I (English Broad-leaf Paradise).....	28	53	17.8	49.0
Malling Type IX (Jaune de Metz).....	50	80	0.0	22.5
Malling Type XIII.....	150	50	5.3	0.0
Doucain (French).....	80	300	51.2	23.0
Total.....	1,308	483		

The greater success with so-called "heel cuttings" of these layered plants may be due to the presence of root primordia in the older wood, and the varying degree of rooting of 1-year wood may be due to the degree root primordia formation has progressed the preceding season, depending upon the season and the time the cuttings were made.

The results are in sharp contrast to the success obtained by trench-layering and mound-layering these types of vegetatively propagated stocks on the same type soil and under the same climatic conditions at Geneva, N. Y., as reported a year ago (1), yet they are of practical significance in that they supplement the rooting of the layered stocks.

If 46 to 67 per cent of the shoots from mounded- and trench-layered plants of these types can be rooted (1) and if then the unrooted shoots from these mother plants can be rooted as hardwood cuttings the following season to the degree here shown, the total percentage of rooted shoots brings the practice within the range of commercial possibility.

HARDWOOD CUTTINGS OF QUINCES

Quince cuttings were taken from layered plants, using four types of quince, and both 1-year and part 2-year wood, and were started in the field April 25, 1931. The importance of a portion or "heel"

TABLE V—COMPARISON OF ROOTING OF HEEL AND 1-YEAR-WOOD CUTTINGS OF QUINCE STRUCK IN FIELD APRIL 25, 1931 (Dug Nov. 24, 1931)

	Wood Used		Per cent Rooted	
	1-Yr. Wood	Heel of 2-Yr. Wood	1-Yr. Wood	Heel of 2-Yr. Wood
Angers Quince (French).....	315	790	7.6	54.1
Angers Quince (English).....	55	—	5.4	—
Angers Quince (Type A).....	140	—	15.0	—
Angers Quince (Type B).....	60	—	0.0	—
Angers Quince (Type C).....	—	50	—	80.0
	570	840		

of 2-year-old wood is well shown in Table V, in which heel cuttings on Angers quince rooted 54 per cent, whereas cuttings with no older wood gave only 7 per cent rooting. Here again the success with heel cuttings may be due to the presence of root primordia in the older wood.

CONCLUSIONS

These results, then, show the difficulty involved in rooting both soft and hardwood cuttings of the hardy fruits; the much greater relative ease of rooting of certain selected strains of fruit plant materials; the great importance of genetic make-up in any rooting response; the increased rooting where heel-cuttings of older wood are used, a fact which probably means the presence of root primordia at the time cuttings are made; and the greater commercial possibility of vegetatively propagated stocks through the rooting of shoots as cuttings, which did not root when layered.

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Vegetative Propagation of Deciduous Fruits

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THE chief reason for wanting to propagate fruit trees asexually has been to secure own-rooted varieties, and the reason for wanting own-rooted varieties has been to eliminate defects and differences in rootstocks and possible weaknesses in the graft union. We in this country have given very little attention to the growing of fruit stocks by vegetative means, and until quite recently the same was true of Europe. To a limited degree we have made use of plum and quince cuttings while in Europe they have long employed stooling for the propagation of quince and Paradise apple stocks. Seedling stocks are still in general use in both hemispheres but there is an incessant demand both here and abroad for something better.

We have tackled the problem in one way, Europeans in another. We have gone in the direction of eliminating stocks while they have tried to improve and standardize their stocks. In our efforts to secure own-rooted stocks or varieties, cuttings either of stems or roots have been employed more generally than layers, not because they were better but because they were cheaper and a more rapid medium of multiplication. European investigators, on the other hand, have pinned their faith to layers. As before stated, our whole ambition seems to have been to produce varieties on their own roots, and horticulturists of the United States being chiefly interested in the apple, have centered their efforts upon trying to multiply varieties of that fruit. J. K. Shaw is easily the pioneer in this field, but his fellow sufferers could be numbered by the score. Practically every experiment station has dabbled with the problem more or less. Auchter (1) has recently published a comprehensive summary of the literature on the principal trials that have been made in this country to root hardwood cuttings of apples as well as other deciduous fruits.

He reviews the experiments of Luke, Shaw, Vierheller, Morris and Jensen, Swingle, Gardner, and Lowrie, with stem cuttings, and Yerkes, Bradford, Upshall, Upshall and Gardner, Scott, and Zimmerman, with root cuttings. Briefly both methods were considered to be impractical and the difficulty was basically the same in both cases, namely, that the parts failed to produce sufficient roots. Many found that the younger the wood, both stem and root, the better roots formed, but there were not enough of them. Year-old seedling stems rooted well and so did the roots when made into cuttings, but unfortunately both were useless for multiplying varieties. Their value for stock purposes was not discussed. My own opinion is that if 2-year-old root systems can be successfully used as cuttings this would be a very promising way of multiplying varieties as well as propagating rootstocks of known performance.

After reviewing some of the difficulties in the way of getting stem and root cuttings to root and saying that we must look to science for a solution of the problems Auchter sums up by saying, "In the meantime American propagators of fruit trees will probably continue to use seedling stocks. Any method of propagation by root or stem cuttings which will replace the seedling stock, at least under the present status of American horticulture, must be so successful that it can be accomplished under field conditions and with a minimum of time and expense. It may be that before such propagation methods are evolved, changing conditions in American horticulture will develop such a need for root systems of a certain vigor, uniformity, adaptability to environmental conditions, or resistance to disease and insects, that some of the more costly propagation methods now available will be employed."

What has been said above refers to results from the usual methods of handling the cuttings, even to the employment of chemical treatment and bottom heat. By a new method of partial layering perhaps any and all deciduous fruits, both trees and shrubs, can be made to root readily from hardwood stem cuttings. This is the so-called "etiolization process" employed with great success by the East Malling Research Station (2) (3) (4). Equal success has attended the use of a special form of layerage perfected by Hatton (5) and his co-workers at the same station. The main idea involved in this last mentioned method is very old but full credit should go to the East Malling Station for demonstrating its possibilities in a practical way. The earliest reference to it I can find is by Esbjerg (6) who tells about its having been used for the propagation of apple trees in Denmark as long ago as 1537. Also A. J. Downing (7) writing in 1869, described a somewhat similar method of laying down entire trees and causing sprouts to arise from the buds.

In principle the new method of propagating by hardwood cuttings is to grow the wood in such manner that the bark at the base of each sprout does not have an opportunity to form its natural color. Perhaps the easiest way is to bank earth around them as they are growing. Strictly speaking they are not etiolated because they have not had any dark color to be bleached out. The color is simply not allowed to form. When detached from the parent plant and used as cuttings all deciduous fruits tried have given a high percentage of rooting. Apparently an inch or so of whitened surface is all that is necessary to cause perfect root formation. The chief drawback to the method is that only one cutting can be made from each sprout. Still this would be a sure method—but a slow one—of growing stocks of known performance. For convenience the parent trees from which cutting wood is to be grown may be set 2 feet apart in nursery rows. This should leave room enough for the mounding process. The cuttings may be treated in the ordinary way, that is by storing them for callusing or by planting them out in late fall. Climatic conditions will determine

whether they should be held until spring before planting. If the ground freezes to a depth of several inches in winter, spring planting is to be preferred. If the ground freezes to a depth of only an inch or two, fall planted cuttings would be safe, particularly if they were slightly mulched with straw or litter.

By the new East Malling method of layerage mentioned the whole tree is laid down and all parts gradually covered with earth as the sprouts arise from the true buds. Closely allied to this form of layerage is the method known in England as stooling but in this country often referred to as mound layering. Stooling has been employed for propagating Paradise apples and quince perhaps as long as these fruits have been grown. Bunyard (8) tells us that the French Paradise can be quite definitely traced back to the year 1507 and is still being grown and that the English Paradise (Type 7), can be traced back to the 17th century. The Portugal quince was brought to England in 1600.

On account of the success of the new method of layerage thus far attained our hopes are again revived that we may now have varieties upon their own roots at will, and in addition a method of multiplying stocks that maintains purity of type. The only disadvantage about it is that it will always be an expensive method of producing either stocks or rooted varieties and probably will never be entirely adopted by our nurseries to the exclusion of older methods.

The new method of layerage may render budding and grafting obsolete by making them unnecessary. This can be done, however, only after we have determined whether our common varieties will thrive on their own roots. Possibly some of our best may demand something else as stocks. It is to be hoped that there may be wide trial of own-rooted varieties in order to acquire information on this point as rapidly as possible.

The chief claim to fame of the East Malling method of layerage is that it makes possible the standardization of stocks that are to be used for budding and grafting purposes.

Stooling and layering are similar in principle. Both depend upon securing sprouts from the true buds which are caused to take root while in place. Experience has shown that some fruits are best handled by one method and some by the other. Trees that are to be mounded, that is stooled, or layered, should be as young as possible when planted. Peaches, all dwarf apples, and perhaps most of the quinces, especially the weaker growing types or varieties, should be stooled. The trees to be stooled may be set 2 feet apart in nursery rows. Allow them to attain one season's growth and then cut them back to within 2 inches of the ground or as low as possible if grafted trees are being used. To secure rooted plants the same season, the mounding process will have to be gradual, more and more fine soil being added as the sprouts elongate. In case any of the sprouts fail to root the basal portions will be "etiolated" sufficiently so that they can be used as cuttings. Best results are secured in stooling

where the soil is mounded to a depth of 6 to 8 inches, especially in the lighter soils. During the mounding process the sprouts may be given more room to develop by crowding the soil around them so they are forced away from the center of the mound. The sprouts are detached in autumn and if rooted are treated as separate trees and if not, as cuttings. By careful manipulation perhaps nearly all varieties of apples, as well as plums, could be rooted in this way.

English experimenters and nurserymen have found it best to layer all plums, standard apples, pears, cherries, and the stronger varieties of quince. For a long time the Mahaleb cherry resisted all attempts at propagation by either layering or stooling. Apparently they could be grown only from greenwood cuttings made from the growing tips. Latterly, however, Mr. Witt of the East Malling Station has found types that layer reasonably well.

To layer by the East Malling method 1-year-old trees should be planted 3 to four feet apart in wide nursery rows. They are inclined along the row at an angle of approximately 30 to 45 degrees from the horizontal, and then left to grow throughout the season. In early spring they are laid down in a trench 2 to 3 inches deep, the main stems and strong laterals being tipped lightly to remove all soft wood. Weak laterals are pruned back to two or three buds. All parts of the stem and branches should be flattened against the ground and held in that position by means of notched stakes or U-shaped pieces of galvanized wire. If any part of the tree can not be flattened against the ground, cut it off.

In the case of plums all layered parts should be covered about an inch deep with fine soil *just before the buds open*. It is important that this layer of soil be not too deep or many of the buds will fail to develop at all. The new shoots are thus forced to push their way through a layer of soil which prevents the bark from coloring and facilitates quick root formation.

Apples, pears, quinces, and cherries, are left uncovered until the sprouts begin to arise. With all species, when the sprouts have reached an average height of about 3 inches, fine soil is shoveled around them and this process is repeated at intervals until the layered stems are covered to a depth of about 6 inches, after which they will require no further attention other than cultivation or irrigation until the dormant season. Care should be taken not to cover the growing points during the mounding process.

In late fall when the leaves are off and the wood is thoroughly dormant the soil is drawn away from the layers and the rooted shoots detached from the parent plant. They should be clipped off with pruning shears or a sharp knife, being careful not to lift the layers out of their position. The rooted shoots are either lined out in the nursery or heeled-in until spring according to local practice and climatic conditions.

The old layers should be completely uncovered and left that way until the following spring, when the program of the previous year is repeated. Care should be taken to see that the layered plants

are flat on the ground as they were originally. If some parts have been raised higher this will result in some of the shoots being covered to a greater depth than others. The trouble is not so much in the difference in covering as in the handicap some will suffer in emerging through the first thin layer of soil. If covered too deeply in the first place the buds fail to get through and if the cover is too shallow, "etiolization" fails to take place and the shoots do not form roots.

Apples are perhaps easier to layer than other fruits. The sprouts may even be 5 or 6 inches high before any mounding is attempted since satisfactory rooting will often take place even though the sprouts have not been properly "etiolated". If rightly handled most trees can be layered annually over a period of several years. The production and removal of sprouts is analogous to heavy annual pruning which of course makes for increased vegetative growth. Too much vegetative growth, however, is undesirable, as the sprouts from such plants do not root so well as those from trees making a more moderate growth. As a matter of fact as the trees advance in age the shoots coming from them tend to decrease in vigor and to increase in number so it is frequently found that with varieties in which rooting is difficult in the early years the sprouts tend to root better and better as the parent trees become older.

The cost of growing layered apple stocks in England for the season of 1930 averaged about \$83.00 per thousand. This figure is based on an average yield of 80,000 to 100,000 trees per acre.

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Notes Upon Stock and Scion Relations in 1931

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PREVIOUS reports have indicated an apparent lack of logical basis for an explanation of "Compatibility" of stocks and scions (1, 2). By varying the cultural technique followed, results have been secured which indicate that the growth of a bud upon a stock in the nursery is decidedly related to the typical growth period of the two varieties. By growth period is meant the relative time at which growth starts in the spring, proceeds through the summer and maturity begins in the late summer or fall. A list of the varieties used as stocks, arranged according to seasonal growth habits this year would be: Tetofsky, Livland, Whitney, Wealthy, Spy, and York. The average growth in centimeters of the early varieties Yellow Siberian and Tetofsky upon these stocks was: 109.2, 93.4, 85.2, 78.8, 63.0, and 42.4. These measurements show a decreasing growth of these scion varieties as the usual maturity of the stock variety becomes progressively later in the season.

Why was this result secured when the data in other seasons seemed to give no indication of a factor being correlated to the growth made between scion and stock—in this case buds upon grafted whips? The difference lies in the budding program followed.

Earlier evidence showed that large and small nursery trees tend to retain that relation in successive seasons even though the original difference may be due purely to nutritional causes. This seems to be true of varieties as well as individual trees. Thus a variety as Tetofsky which makes a small first season growth as compared to Spy for example, would be of unequal value as a stock merely because of a difference in growth rate. On the other hand, it is common for nursery trees of unequal size to make much more nearly the same growth after being cut back. This applies to varieties as well as individuals of a variety. Consequently the grafts of 1929 were not budded that year but were cut back in the spring of 1930 and budded in August, 1930. This gave stocks of more nearly the same vigor than occurs the first season and should permit of a better measurement of the relative effect of the stock upon a scion variety, due to the partial elimination of a serious variable, the unequal size of whips of different varieties if they are budded during the first growing season. That is, the growth secured in 1931 should be more nearly a true response of stock influence than that secured in previous years. It appears that the data of this season do indicate a correlation between the growth of two early maturing varieties and the seasonal growth period of the stocks used.

The growth of the late maturing varieties York and Winesap on stocks having different seasonal growth habits follows: Tetofsky, 130.9; Livland, 110.4; Whitney, 117.1; Wealthy, 120.7; Spy, 104.2;

and York, 121.7. These data indicate no clear preference of these late maturing varieties for the early or late stocks used. The large growth on the early stock, Tetofsky, does however, deserve further comment. Histological studies have shown varieties as York to be limited in growth by a slow or seasonally tardy accumulation of carbohydrates when growing vigorously as in the nursery. Thus growth would be increased under conditions favoring starch formation. It has been observed that the greater growth of York on the dwarfing stock Malling IX (2) as compared to a somewhat smaller growth on the vigorous stock Malling XII is correlated with starch condition. On the other hand, the dwarfing effect of IX upon Whitney is associated with very early accumulation of reserve starch. (Shading of this stock and scion combination increases the shoot growth.) It is also commonly noted that late varieties as Winesap and York grow well upon such stocks as Virginia Crab, a vigorous but early maturing sort.

The decided tendency for a variety to grow best when grafted on its own seedlings may be due to the seasonal growth habits being combined in such a graft.

What results will follow from future experiments on the influence of seasonal growth period of stock and scion upon the growth of grafts will not be prophesied. It is believed, however, that this factor has a large influence upon compatibility. In attempting to discover a "good" stock for orchard trees, however, too direct an application of nursery growth responses might lead to erroneous conclusions.

It has been consistently reported by English workers that little to no scion influence could be noted upon the type of root growth made by the Malling stocks when grafted to common English varieties. It may have been inferred by some readers that this was evidence of lack of scion influence. The question remained, however, of what the original rooting habits were of these varieties or of what effect they might have upon seedling root grafts. Scions of the following varieties were secured from the Long Ashton Experiment Station and root grafted in March, 1931, using a three-bud scion and approximately a five-inch root: Bramley, Beauty of Bath, Cox Orange, Grenadier, Grieve, Lane's Prince Albert, Newton Wonder, Tyler's Kernel, and Worcester Pearmain. Upon digging these grafts in November it was found that all but Tyler's Kernel had almost exactly the same type of root, having many, horizontally-growing roots along the stock with a tendency to cluster near the soil surface. Tyler's Kernel produced the same type of root except for a more even distribution along the stock. The amount of root in relation to the size of the whips was very different being greatest under Lane's and Grieve, and least for Cox, Beauty, and Bramleys with the other varieties having an intermediate amount of coarseness. In the same planting the root types of the following varieties were very different one from the other and also from the English kinds: Yellow Siberian, Fameuse, Starking, York, and

Whitney. From this first trial it would appear that the English varieties used, do show scion influence when grafted upon straight seedling roots but that those used produced such similar roots that scion influence would hardly be detected by a comparison between these varieties unless the amount of roots produced was especially noted.

When buds were set upon yearling grafts the resulting growth was more uniform than with buds upon seedlings, the coefficients of variation this season being 13.4 and 22.3. This is an interesting result in view of buds on seedlings being regularly more uniform than the growth of bench grafts. Heavy cutting back after budding gave more uniformity than occurred in the original grafts. The growth of the buds on the grafts was more uniform than on seedlings because of the influence of the intermediate scion (a clon).

A repeated result is for root-grafted trees to have a uniform root type within a variety and for stem-grafted trees to have variable types of roots presumably much like the ungrafted seedlings. (The amount of rooting is influenced by the scion variety on both high [stem] grafted and budded trees.) That is, the stem portion of the stock appears to "regulate" scion influence. When roots are exposed to sunlight they take on somewhat the external appearance of stems. Would such a root fail to show scion influence? Some scions were set on roots 8 or 9 inches long. These were planted with the union above the soil. From a limited number of grafts which survived a difficult growing season this year, it appears that these grafts do not show the degree of scion influence which results from normal planting of the union below the surface of the soil. If further trials verify this observation the source of stock influence and absence of scion influence on stem grafts may be later uncovered, probably in the phloem region.

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Influence of Size of Mahaleb Seedlings on Nursery Grades

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IN the 1929 report of this Society data secured from an unusually fine block of seedlings and resulting nursery stock, were presented. In 1930 similar data secured from a very poor block of seedlings and one-year trees were presented.

TABLE I—INFLUENCE OF SIZE OF MAHALEB SEEDLINGS ON NURSERY GRADES

Seedling Classes	Ave. Diam. Seedlings (inches)	Seedlings Larger or Smaller than 8/16 in. (Per cent)	Per cent Making 1-Year Trees 11/16 in. or Larger	Correlation Between Size of Seedlings and Size of 1-yr. tree
1928-29.....	0.52	—	—	—
Below 8/16 in.	—	32	20	.685±.0158
Above 8/16 in.	—	68	82	
1929-30.....	0.38	—	—	—
Below 8/16 in.	—	83	6	.654±.0098
Above 8/16 in.	—	17	40	
1930-31.....	0.57	—	—	—
Irrigated.....	—	—	—	—
Below 8/16 in.	—	15	6	.661±.021
Above 8/16 in.	—	85	77	
1930-31.....	0.49	—	—	—
Not irrigated..	—	—	—	—
Below 8/16 in.	—	41	11	.7209±.0146
Above 8/16 in.	—	59	68	

In the very dry season of 1930 two short rows of seedlings were irrigated with suitable check rows on either side. The number of trees in this test was smaller than in previous years. Irrigation in 1930 increased the average diameter of seedlings from 0.49 inch to 0.57 inch. This 0.08-inch increase in size of seedlings, due to irrigation, resulted in 47 per cent more No. 1 trees. This result confirms the suggestion that the size of 1-year cherry trees may depend quite as much upon the growing conditions during the seedling stage as upon the growing conditions during the year the bud is growing.

Of 200 non-irrigated seedlings, less than 8/16-inch in diameter in 1930 when budded, only 11½ per cent made trees 11/16-inch in diameter or larger in 1931. Of 292 non-irrigated seedlings 8/16-inch or larger in 1930, 68 per cent produced nursery trees 11/16-inch or larger in 1931.

Of 49 irrigated seedlings less than 8/16-inch in diameter in the fall of 1930, only six per cent produced trees 11/16-inch or larger in 1931. Of 266 irrigated seedlings 8/16-inch or larger in 1930, 77 per cent produced trees 11/16-inch or larger in 1931.

Sixty-six per cent of 315 seedlings irrigated in 1930 produced trees which were 11/16-inch or better in the fall of 1931. Only 45 per cent of 492 non-irrigated seedlings produced 1-year trees 11/16-inch or better in 1931.

Tukey and Brase (1) report a similar correlation for Mazzard seedlings and 1-year trees of $0.612 \pm .025$.

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A Comparison of the Variability in Growth of Several Varieties of Apple Trees Growing on Seedling Roots and Upon Their Own Roots

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THE author is unaware of any published information comparing the variability in growth of apple trees on their own roots and that of the same variety on seedling roots. Studies (1, 8, 9, 10) have been reported, wherein, data has been presented using trees on clone roots for comparison with trees on seedling roots with respect to variability in growth. Briefly, the results obtained were: Roberts (9), comparing the variation in growth of yearling trees on seedling and clone stocks found "the trees on seedlings more variable in growth than those on layers" but he attributed most of this difference to other causes.

Anthony and Yerkes (1) comparing the growth made by 1-year Stayman trees on seedling roots with that of Stayman trees on clone roots state, "the more uniform sizing of the trees on commercial seedling roots has continued to maintain a higher degree of uniformity through 2 years in the orchard." From additional studies, however, they conclude that "the use of clone roots in at least four out of five cases has resulted in greater uniformity in the nursery experiments reported. Roberts (10) states that "grafting upon rooted layers does not insure uniform trees." He also states that, "it even appears probable that the commonly reported uniformity of nursery trees on clonal stocks is the result of the method of grafting rather than being due to the stock used."

Hatton (8) reports an instance where 14-year-old Early Victoria apple trees on seedling stocks are compared in variability of growth and yield with a series on vegetatively raised stocks, although the vegetative stocks were possibly mixed Paradise. He found that "the coefficient of variability for cropping was 57.1 for the trees on Crab and 36.5 for those on Paradise; for girth of stem, the figures are even more striking, 27.4 as against 12.9." As 1-year-olds, all trees had been carefully graded for size. He further states that "there is not a single instance where the sets of trees on seedling Crab are more uniform, and a number in which they have proved definitely more variable."

MATERIAL

The scion-rooted trees used in this study were produced by the long scion-nurse root method as described in detail by Auchter (1). The grafts were planted in the nursery row in the spring of 1927 and dug in the spring of 1929. The trees were graded according to the quantity of scion roots formed so that within each variety were groups with many, medium and few scion roots. In all of the scion rooted

trees selected for replanting the seedling or nurse root was removed above the graft union. They were then weighed and calipered. A similar number of 2-year trees of good grade and of the same varieties but on seedling roots were purchased from nurserymen. A medium-sized grade of Rome Beauty was necessarily used. The orchard at planting time comprised:

Two rows of Yellow Transparent: 40 scion rooted and 40 on seedling roots.

Two rows of Stayman Winesap: 40 scion rooted and 40 on seedling roots.

Two rows of Delicious: 40 scion rooted and 40 on seedling roots.

Four rows of Grimes Golden: 80 scion rooted and 80 on seedling roots.

Six rows of Rome Beauty: 120 scion rooted and 120 on seedling roots.

Soon after planting, one-third of the previous season's terminal growth of each tree was removed. This is the only pruning given the tree since planting. The weight of prunings was deducted from the original weight of each tree at time of planting.

During the past three seasons, the trees have been well cared for, receiving cultivation and cover crops of soybeans, and in 1931 applications of N, P and K using $\frac{1}{2}$ pound of NaNO_3 around each tree in early spring and 50 lbs. each of elemental P and K per acre at time of drilling in the soybeans in June.

As the points of particular interest are the variability and growth of the two types of material, the coefficient of variability and the average mean will be used as units of measure, although the standards of deviation are presented.

At the start of the experiment, it was evident from the coefficients of variability presented in Table I that, excepting Yellow Transparent the trees on seedling roots were much less variable in weight than those on their own roots. The trees of each variety on seedling roots, except Rome Beauty, had a mean weight greater than that of the trees on their own roots.

The coefficients of variability (Table II) show that the trees on seedling roots were much less variable in height than the scion-rooted trees, although the differences in Yellow Transparent and Grimes Golden were insignificant. All varieties on seedling roots, excepting Rome Beauty, were taller than the scion rooted trees, although Stayman Winesap was not significantly so.

In circumference the coefficients of variability (Table II) show that the seedling rooted trees were much less variable than the scion-rooted trees at the start of the study, although Yellow Transparent was not significantly so.

At time of planting, excepting Rome Beauty, the trees on seedling roots had a larger average mean circumference than the scion-rooted trees.

TABLE I—THE MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIABILITY OF TREES. SPRING 1929.

Varieties	Weight of Trees (Grams)				
	Type of Roots	No. Trees	Mean 1929	S.D. 1929	C. V. 1929
Yellow Transparent.....	Scion	40	157.02 ± 3.86	36.16 ± 2.73	23.03 ± 1.74
	Seedling	40	272.02 ± 8.50	79.67 ± 6.01	29.29 ± 2.21
Difference and probable error of difference.....			115.00 ± 9.34	43.51 ± 6.53	6.26 ± ¹ 2.8
Stayman Winesap.....	Scion	40	204.24 ± 7.27	68.15 ± 5.14	33.37 ± 2.52
	Seedling	40	256.48 ± 3.56	33.37 ± 2.52	13.01 ± .98
Difference and probable error of difference.....			52.24 ± 8.10	34.78 ± 5.73	20.36 ± 2.7
Delicious.....	Scion	40	165.92 ± 7.74	72.59 ± 5.47	43.75 ± 3.30
	Seedling	40	276.72 ± 4.08	38.24 ± 2.88	13.82 ± 1.04
Difference and probable error of difference.....			110.80 ± 8.75	34.35 ± 6.18	29.93 ± 3.36
Grimes Golden.....	Scion	80	172.10 ± 5.91	78.34 ± 4.18	45.52 ± 2.43
	Seedling	80	349.10 ± 7.29	96.62 ± 5.15	27.61 ± 1.47
Difference and probable error of difference.....			177.00 ± 9.39	18.28 ± 6.63	17.91 ± 2.83
Rome Beauty.....	Scion	116	244.80 ± 6.48	103.3 ± 4.57	42.20 ± 1.87
	Seedling	120	187.16 ± 2.01	32.71 ± 1.42	17.48 ± .76
Difference and probable error of difference.....			57.64 ± 6.79	70.59 ± 4.79	24.72 ± 2.02

¹Difference is not significant.

To summarize briefly: at the start of the experiment in the spring of 1929, the coefficients of variability with respect to the weight, height, and circumference of the trees are much greater in the scion-rooted trees. This is undoubtedly due to the fact that the scion-rooted trees were selected from a smaller population than the seedling-rooted trees and included good, medium, and poorly rooted trees. The seedling-rooted Yellow Transparents are an exception to the above, as noted from the differences and their respective probable errors. All varieties on seedling roots had greater weight, height, and circumference with the exception of height in Rome Beauty, and Stayman Winesap. In brief, the trees on seedling roots had an advantage over the scion-rooted trees at the start of this study with respect to uniformity and size.

TABLE II.—THE MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIABILITY OF HEIGHT AND CIRCUMFERENCE OF TREES IN THE SPRING OF 1929 AND FALL OF 1931

Variety	Type of Roots	Trunk Circumferences (Cm.)									
		Mean					S. D.		C. V.		
		No. Trees	1929	No. Trees	1931	1929	1931	1929	1931	1931	
Yellow Trans.	Scion Sdlg.	40	3.10 ± .065	40	8.9 ± .282	.607 ± .046	2.046 ± .199	19.58 ± 1.48	29.7 ± 2.24		
		40	3.71 ± .069	40	8.8 ± .243	.649 ± .049	2.285 ± .172	17.54 ± 1.32	25.9 ± 1.95		
Difference P. E. D.			.61 ± .095		2.1 ± .372	.042 ± .067	.361 ± .263	2.04 ± 1.983	3.8 ± 2.97		
Stayman	Scion Sdlg.	40	3.56 ± .072	39	9.6 ± .214	.676 ± .051	1.982 ± .151	18.78 ± 1.42	20.6 ± 1.57		
		40	4.07 ± .036	36	11.2 ± .214	.336 ± .025	1.903 ± .151	8.19 ± .62	17.0 ± 1.35		
Difference P. E. D			.51 ± .081		1.6 ± .303	.340 ± .057	.079 ± .214	10.59 ± 1.550	3.6 ± 2.07		
Delicious	Scion Sdlg.	40	3.07 ± .013	30	8.94 ± .256	.588 ± .044	2.079 ± .181	18.96 ± 1.43	23.4 ± 2.04		
		40	4.16 ± .028	40	11.4 ± .183	.267 ± .020	1.718 ± .130	6.35 ± .48	15.1 ± 1.14		
Difference P. E. D.			1.09 ± .031		2.46 ± .315	.321 ± .048	.361 ± .223	12.61 ± 1.505	8.3 ± 2.34		
Grimes	Scion Sdlg.	80	3.33 ± .055	79	10.4 ± .205	.723 ± .038	2.698 ± .145	21.90 ± 1.17	25.9 ± 1.39		
		80	4.73 ± .055	69	11.6 ± .172	.725 ± .039	2.114 ± .121	15.43 ± .82	18.2 ± 1.05		
Difference P. E. D.			1.4 ± .078		1.2 ± .268	.002 ± .055	.584 ± .189	6.47 ± 1.429	7.7 ± 1.74		
Rome	Scion Sdlg.	116	3.9 ± .044	108	8.6 ± .101	.710 ± .031	1.559 ± .072	18.20 ± .81	18.1 ± .83		
		120	3.7 ± .024	110	9.0 ± .107	.389 ± .017	1.694 ± .076	10.51 ± .46	18.5 ± .84		
Difference P. E. D.			.2 ± .05		.4 ± .147	.321 ± .035	.105 ± .105	7.69 ± .93	4 ± 1.18		

Yellow Trans.	Scion Sdlg.	Height of Trees (Ft.)		1,500 ± .113 1,110 ± .084	22.5 ± 1.69 17.7 ± 1.35	26.3 ± 1.98 17.5 ± 1.34
		40	40			
Difference P. E. D.				.390 ± .141	4.8 ± 2.16	8.8 ± 2.39
Stayman	Scion Sdlg.	40	40	.748 ± .057 1,044 ± .083	23.7 ± 1.81 11.4 ± .91	10.8 ± .82 14.6 ± 1.15
Difference P. E. D.				.296 ± .101	12.3 ± 2.03	3.7 ± 1.41
Delicious	Scion Sdlg.	40	40	1,088 ± .093 .800 ± .080	23.7 ± 2.06 9.7 ± .73	14.8 ± 1.29 11.1 ± .84
Difference P. E. D.				.268 ± .111	14.0 ± 1.29	3.7 ± 1.54
Grimes	Scion Sdlg.	80	80	.938 ± .050 .995 ± .057	23.9 ± 1.28 20.5 ± 1.11	13.6 ± .73 14.4 ± .83
Difference P. E. D.				.057 ± .076	3.4 ± 1.69	.8 ± 1.11
Rome	Scion Sdlg.	116	120	.794 ± .036 .806 ± .037	18.5 ± .85 11.2 ± .51	14.4 ± .66 15.2 ± .69
Difference P. E. D.				.012 ± .052	7.3 ± .991	.8 ± .955

¹Sdlg. is abbreviation for seedling.

²Indicates that difference is not significant.

Gardner and Yerkes (7) in a study on the relation of size of apple seedlings to growth of scion variety found that "the size of stock, whether the result of inherent vigor or environmental conditions, deserves more serious consideration."

After three seasons' growth (Table II) the Yellow Transparent is the only variety on scion roots that has a significantly greater coefficient of variability in height on scion roots than on seedling roots.

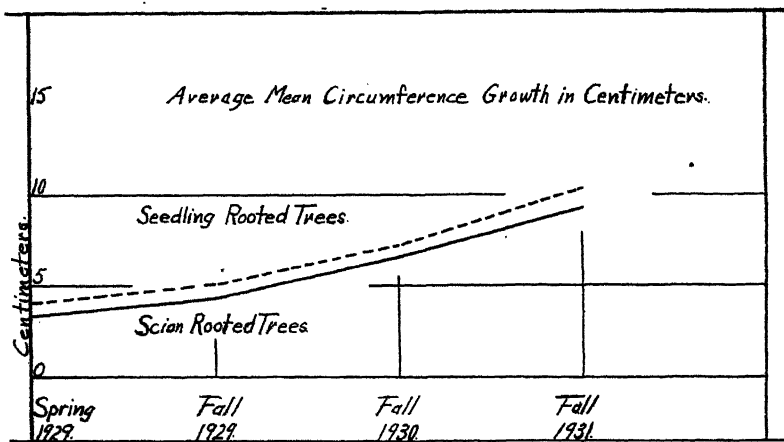


FIG. 1. Average mean circumference growth in centimeters.

The probable error of the difference in the other varieties indicates that none are significant. In all other varieties the coefficient of variability has decreased on scion roots while it has increased on seedling roots with the exception of Yellow Transparent and Grimes Golden. In general, the scion-rooted trees now nearly equal the seedling-rooted trees in uniformity of height.

Table II shows that the mean height of the trees on seedling roots was greater in the spring of 1929 in all varieties except Rome Beauty, although not significantly greater in Stayman Winesap. In 1931 (Table II), the trees on seedling roots have a significantly greater mean height only in Yellow Transparent, for the scion-rooted trees of the other varieties have gained sufficiently to now equal or nearly equal in height similar varieties on seedling roots.

By the fall of 1931 (Table II) the difference in circumferential variability between the two groups had been much reduced, due largely to the increasing variability in the trees on seedling roots. It will be noted (Fig. 2) that most of the increase in variability in circumference in the scion-rooted trees occurred during the 1931 season, while it has been continuous in the trees on seedling roots. Due to lack of space the data is not presented, but it was found that the increases in circumferential variability between the spring of 1929 and the fall of 1931 were significant in all varieties on seedling roots ex-

cept Grimes Golden. None was significant on scion roots except in Yellow Transparent.

In brief, the circumferential variability of the trees on scion roots has not increased significantly, whereas, that of the trees on seedling roots has increased greatly and significantly.

Data unpublished because of lack of space show that the trees on scion roots have decreased significantly in four of the five varieties

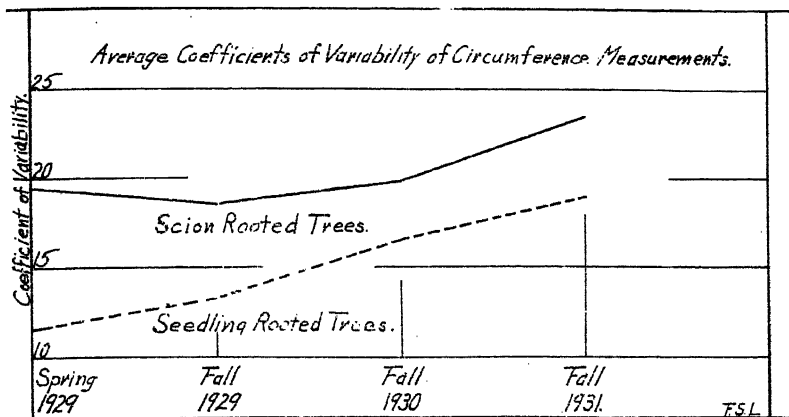


FIG. 2. Average coefficients of variability of circumference measurements.

with respect to variability in height during the 3-year period. The trees on seedling roots decreased significantly in but one variety and increased significantly in one. Two of the other varieties increased and one decreased but not significantly.

Beaumont (4) found in a study on the vigor of apple seedlings over a 6-year period that there was a general tendency for the trees to become slightly more uniform in trunk diameter with increasing age, although there were significant differences in both directions. He found the coefficient of variability to decrease more consistently and significantly with respect to height than with diameter.

The next question is whether the decrease in variability in the scion-rooted trees is associated with good or with poor growth.

When one considers the lack of uniformity in weight, height, and circumference of the scion-rooted trees at the start of the study as compared to the uniformly calipered and graded trees on seedling roots, it seems almost unbelievable that 3 years could be productive of the changes that have occurred. The removal of the seedling roots from the scion-rooted trees would be, one would think, an operation sufficient to disrupt the metabolism of the tree for some time, but as is evident from the data (Fig. 1), the scion roots quickly adjusted themselves to their task, with the result that their average percentage¹

¹Although it is not customary to average averages, it is herein referred to several times for brevity when an analysis of the individuals making up the average shows that the majority have the same trend.

increase in circumferential growth by the fall of 1929 was slightly greater (Fig. 3) than that of the trees on seedling roots. It was greater also at the end of the 1930 and 1931 seasons.

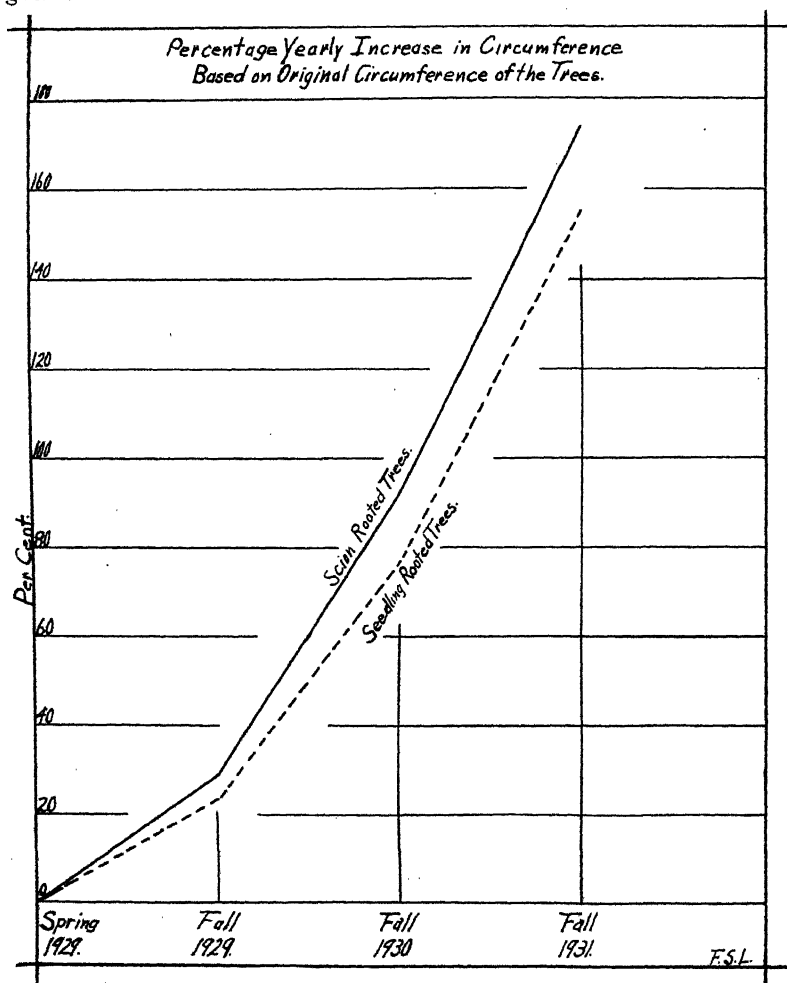


FIG. 3. Percentage yearly increase in circumference based on original circumference of the trees.

It will be recalled that in the spring of 1929 the trees on seedling roots had a significantly larger mean circumference than those on scion roots, except Rome Beauty, in which instance the reverse held true. By the fall of 1931, Stayman Winesap, Delicious, and Grimes Golden were still significantly larger in circumference on seedling roots than on scion roots. The scion-rooted Yellow Transparent had

gained on the seedling-rooted Yellow Transparent sufficiently to make the difference between them insignificant and the seedling-rooted Rome Beauty had gained on those on scion roots to a similar extent.

The mean circumferential growth of both groups of trees has been excellent (Fig. 1). The scion rooted trees have done much better than was expected having on a percentage basis increased 175.9 per cent and those on seedling roots 154.86 per cent. In actual circumferential increase, the seedling-rooted trees which were significantly larger at time of planting, except Rome Beauty, have averaged $6.33 \pm .189$ cm. to the scion-rooted trees, $5.9 \pm .216$ cm. growth, a gain of $.43 \pm .286$ cm. which is insignificant. The seedling rooted trees are significantly larger in three instances and insignificantly in another. The scion-rooted trees are insignificantly larger in one instance.

In percentages, based on the original average circumference of the trees, the scion-rooted trees have excelled in Yellow Transparent, Delicious and Grimes Golden.

It is thus apparent that the scion-rooted trees have grown very well in comparison with the trees on seedling roots and that their tendency to remain rather constant with respect to their original variability has not been at the expense of growth.

Bailey (3), reporting on the trunk diameter of trees in the Root and Scion Orchard at Massachusetts, states, "the first thing noticeable in this figure (referring to his Fig. 1) is the larger growth of the own-rooted trees of the more vigorous varieties...." All of the other trees were on vegetatively propagated roots and therefore no similar varieties on seedling roots are presented for comparison. The results, however, showed that own-rooted trees grew well.

Cullinan (5) states, "Comparison of the growth of Grimes on its own roots with that on Virginia Crab stock suggests that the Virginia Crab stock has invigorated the scion variety."

Vyvyan (11) has made very excellent detailed comparisons of the growth made by apple trees on clone and seedling roots but as the data for the individual trees of each type is not presented a comparison of their variability cannot be made.

Esbjerg (6) 1930, of Denmark has found varieties on their own roots to grow and yield well and to be preferred by growers in certain districts to the grafted or budded nursery trees. He presents data on yields of scion- and seedling-rooted trees but none on their comparative variability with respect to growth.

Although we must still look to the future for a definite answer to our question of whether a group of a given variety of scion-rooted trees will develop into a less variable group at maturity, than seedling-rooted trees of that variety under the same environmental conditions, the results obtained after three growing seasons in the orchard in question, speak most favorably of the scion-rooted trees. This is especially true with respect to the slight change occurring in their circumferential variability from 1929 to 1931 as compared to similar varieties on seedling roots. It is felt that if a larger number of scion-

rooted trees had been available at time of transplanting to the orchard, the original variability of this group of trees could have been greatly reduced, thus making the two groups more comparable at the start.

The growth of the scion-rooted trees has been most excellent considering the injury incurred at time of removal of the seedling root, and as viewed in the orchard at this time they are indistinguishable from the trees on seedling roots.

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PLATE I. Young pear trees used as inarches. In this illustration the tops of the inarches have been removed at the time the grafting was done.

A Study of Growth of Pear Inarches¹

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DURING the spring of 1929, California pear growers planted approximately 300,000 French pear seedlings, *P. communis*, adjacent to the trunks of pear trees on Japanese rootstocks (*P. serotina*). These seedlings were to be inarched into the mature trees, thus giving the trees a different root system. This was following the observations of Heppner (2) that the black-end condition was associated with the Japanese rootstock. At that time no experience had been had with inarching of deciduous fruit trees when the work was done on a large scale.

TABLE I—RELATION OF TIME OF INARCHING TO THE TOTAL INCREMENT OF GROWTH MADE AT THE END OF THE THIRD GROWING SEASON

Time of Inarching	Increment of Growth (mm.)
May	5.8±.343
June	5.2±.424
July	4.6±.573
August	5.5±.600
September	5.7±.526

Diameter measurements of about 700 inarches were made to secure some information upon the increments of growth. The measurements were made in three different orchards. The owner of orchard No. 1 used seedlings that were too small for budding, (average diameter of 6.2 mm.). The inarches in orchard No. 2 were supplied by the University Farm and had an average diameter of 10.3 mm. Orchard No. 3 was inarched with budded trees of the Old Home variety (*P. communis*) on French seedlings. These trees had an average diameter of 8.9 mm. The distribution of sizes in all cases was approximately normal. The inarches in orchard No. 1 ranged from 3.5 mm. in diameter to 9.5 mm. The class of greatest frequency was 6.0 mm. Those in orchard No. 2 ranged from 5 to 19 mm. in diameter with the class of greatest frequency at 9.0 mm. The inarches in orchard No. 3 were from 4.0 to 12.0 mm. in diameter. The class of greatest frequency was at 9.0 mm. Each inarch was tagged and a spot of white paint placed on it just below the point of union (Plate I.). The measurements were made at this point each time with a pair of calipers. The first measurements were made in the spring of 1929 and subsequent measurements made at the end of each growing season.

¹The word "inarch" is used as a noun by California orchardists to designate young trees which have been planted adjacent to more mature trees for the purpose of making an approach graft with the older tree. In this paper these young trees will be called "inarches".

In one group the inarching was done on the first of each month for five consecutive months beginning May 1. Thirty-three inarches on 11 trees were made each month. Table I gives the data in relation to the time of inarching. This experiment was performed in orchard No. 3.

TABLE II—RELATION OF METHOD OF INARCHING TO THE TOTAL INCREMENT OF GROWTH MADE AT THE END OF THE THIRD GROWING SEASON

Method	No. of Inarches	Increment of Growth (mm.)
Tops removed.....	82	5.0±.276
Tops not removed.....	66	6.9±.344

Due to the large probable error there is no significant difference in the increment of growth made in the various groups. However, an interesting trend may be shown by the data. The increment of growth decreases consistently from May to July and then increases until September. The curve formed by these increments of growth suggests a similarity to the curves of some storage food materials. It may be that if many more inarches had been included in each of these measurements the differences would have attained a statistical significance. The total increment of growth is small, only a little more than half the original size of the inarches.

Two methods of inarching were tried in a second group. The inarching was done with an approach graft. In one case the top of the young tree was removed at the top of the incision as soon as the graft was made. In the second case the top of the young tree was allowed to remain until the end of the first growing season, when it was removed. Table II presents this data. This was done in orchard No. 3. The difference between the two groups was $1.9 \pm .441$ mm., a difference that is statistically significant.

TABLE III—RELATION BETWEEN ORIGINAL SIZE OF INARCH AND INCREMENTS OF GROWTH

Orchard No.	No. of Inarches	Increment Made in	Coefficient of Correlation
1.....	233	2 years	+ .340±.039
2.....	145	1 year	— .201±.054
2.....	145	2 years	— .199±.055
3.....	253	2 years	— .356±.055
3.....	253	3 years	— .379±.054
3.....	253	2nd year only	— .288±.043

Our field observations at the end of the first growing season indicated that there was a wide difference in the size of the inarches, much greater than there seemed to have been at the time the inarching was done. One explanation suggested was that those inarches which were the largest had made the greatest increment of growth by virtue of their inherent vigor. If this were true the inarches which made the greatest increment of growth were in all probability also the largest at the time of planting and grafting.

Table III shows the coefficients of correlation when the increments of growth have been correlated with size at the time of the first measurement.

The coefficients of correlation are in all cases small and cannot, in themselves, be considered significant. One interesting relationship is shown by this table. The only case where a positive correlation was found was in orchard No. 1. This was the orchard where the very small seedlings were used. The correlation is negative for orchards No. 2 and No. 3 where the inarches were much larger than in orchard No. 1. In all probability a large number of the seedlings in orchard No. 1 were too small for grafting. In this case a positive correlation would be expected as the larger seedlings were more nearly the best size for working. In a graft of the nature of an inarch the best results are perhaps secured when the greatest number of points of contact are made between the cambiums of the two trees. Not only is it important to have seedlings large enough to graft, but it is also important that they be straight and pliable enough to be easily and snugly fitted and nailed into the incision on the mature tree. All, except a very few, of the inarches in orchards Nos. 2 and 3 were above 7.0 mm. in diameter, with the class of greatest frequency at 9.0 mm. At least half the inarches were larger than this, some much larger. The negative correlation found on these two ranches suggests that not only may an inarch be too small for the best results but also it may be too large for easy and efficient manipulation during the grafting process. Difficulty has always been experienced in finding sufficient space for the roots of the inarches around the base of the mature tree. Inarches with large root systems would suffer most in being crowded or in having their roots pruned more heavily at planting time. This is perhaps another factor associated with the negative correlation. There are no doubt many factors which are related to the growth of inarches and which may be as important as the two suggested.

The low correlation between size and increment of growth is in agreement with the findings of Gardner and Yerkes (1) that size in apple seedlings was not an indication of inherent vigor. In the case of pear trees used for inarching it seems that original size as an indication of inherent vigor is of much less importance than when it functions as a factor in the efficiency of the grafting process.

The orchard on ranch No. 3 had rows of Buerre Bosc, Buerre Hardy, and Winter Nelis as pollenizers. However, these varieties had not been included in the original planting scheme of the orchard but had been topworked a few years after the orchard had been set out. The trees in these rows then consisted of, the top of the particular winter variety, the Bartlett trunk and the Japanese rootstock. These trees had been inarched in the same manner as the Bartlett trees. Unfortunately no measurements were made of the inarches on these trees at the time the inarching was done. A striking difference in size between the inarches on these trees and those on the Bartlett was noticed at the end of the third season.

Measurements of about 200 inarches were made on each of these varieties to compare their size with that of the inarches on the Bartlett trees. Table IV presents the data.

TABLE IV—THE EFFECT OF THE VARIETY TOP ON THE SIZE OF INARCHES AT THE END OF THE THIRD SEASON

Variety	Size of Inarches (mm.)
Bartlett.....	14.6±.162
Bosc.....	16.0±.231
Hardy.....	16.0±.224
Winter Nelis.....	16.8±.212

The difference in size between young trees inarched on Bosc and Bartlett was $1.4 \pm .283$ mm.; between Hardy and Bartlett, $1.4 \pm .258$ mm.; and between Winter Nelis and Bartlett, $2.2 \pm .267$ mm.

If the assumption is made that the 200 inarches on the Bosc, Hardy, and Winter Nelis trees were of the same average size as those on the Bartlett trees, then the variety top has had a significant effect on the increment of growth of the stem portion of the inarch. Tufts (3) has found a high correlation between trunk size and size of root system in young trees. It is very probable that the root system of the inarch is influenced very much like its stem.

SUMMARY

The increment of growth made by pear inarches does not seem to be influenced by the time when the inarching is done. Inarches which had the tops left on made a greater growth than inarches whose tops were cut off at the time of inarching. The difference, however, was not large by the end of the third growing season. There is no correlation between the initial size of an inarch and the increment of growth made either during the first year, the first two years, or by the end of the third year. The data indicate that factors other than size are more important in the growth made by the inarches. The variety of the top seems to have a distinct effect upon the growth of the inarch, the varieties Bosc, Hardy, and Winter Nelis, having larger inarches by the end of the third season than the Bartlett.

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The Effect of Paraffining, Pruning, and Other Storage Treatments Upon the Growth of Roses and Cherry Trees

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THE work here reported was begun at the request of New York nurserymen who yearly experience heavy losses with nursery stock which must be replaced because of failure to start and to make satisfactory growth in the hands of the planter. The losses are particularly heavy in the case of sweet cherry trees, though it is appreciable with roses and peaches, as well, whereas apple and pear trees suffer to a lesser degree.

Attention is at once focused upon the method now in vogue of handling nursery stock, in which the plants are dug in the fall of the year and stored over winter in nursery cellars for spring delivery. There is much variation in the types of cellars used, the humidity, the temperature, and the disposition of the plants in the cellar. Stock may be stood upright with the roots in moist sand ("trenched"), it may be stored horizontal in vertical bins with the roots in moist sand, or it may be piled horizontal with the roots exposed and covered lightly with moist excelsior and moss ("corded").

Because of the suggestions that at once come to mind as to places in these practices where something might occur that might be detrimental to the plants, the following methods of treatment in storage were tried, all treatments being conducted in a modern concrete nursery cellar, adequately ventilated, and with relative humidity of 93 to 95 during the winter season, and varying in temperature between 33 and 45 degrees Fahrenheit, although in the vicinity of 40 degrees most of the storage season.

- I. Corded in bins.
- II. Corded in bins and tops pruned.
- III. Corded in bins and tops coated with melted paraffin.
- IV. Trenched in sand.
- V. Corded in bins and tops coated with yellow crude scale wax.
- VI. Corded in bins and tops pruned and coated with melted paraffin.

"Cording" consisted in laying the trees tightly together horizontally with their roots exposed and covered with moist excelsior. "Pruning" consisted in cutting back the branches $\frac{1}{3}$ to $\frac{1}{2}$ their length. "Trenching" consisted in setting the trees in damp sand to the depth they stood in the field. "Paraffining" and "waxing" consisted in dipping the tops in melted paraffin or wax maintained at a temperature of 175 degrees Fahrenheit.

The stock used was 500, 2-year-old sweet cherry trees of the Black Tartarian, Napoleon, Schmidt, and Yellow Spanish varieties, se-

cured from five large commercial nursery companies in the western New York nursery section, and delivered for storage the first week in December, 1929.

The following spring the cherry trees were planted out-of-doors in a clay loam soil of high fertility, and kept clean cultivated and thoroughly sprayed throughout the season.

TABLE I—EFFECT OF STORAGE TREATMENT OF NURSERY STOCK UPON SURVIVAL OF CHERRY TREES IN THE ORCHARD

Treatment	No. Planted	No. Died	Per cent Died
1. Corded.....	81	27	33.3
2. Corded and pruned.....	82	27	32.9
3. Corded and paraffined.....	76	28	36.8
4. Trenched in sand.....	83	26	31.3
5. Corded and coated with yellow crude scale wax.....	83	36	43.3*
6. Corded, pruned and paraffined.....	83	25	30.1

*Includes an unequal number of trees from one nursery supplying inferior stock.

It is seen at once from Table I that the storage treatments have had no appreciable effect upon the trees. The losses are approximately 1/3 of the number of trees planted, regardless of the method of storage, with the exception of Treatment V, in which a larger number of trees was included from a nursery supplying inferior stock, thereby bringing this treatment abnormally high.

Arranging the data according to the source of stock, as seen in Table II, shows that the mortality of trees from certain nurseries is high, while from others it is low, regardless of storage treatment.

TABLE II—EFFECT OF SOURCE OF NURSERY STOCK UPON SURVIVAL OF CHERRY TREES IN THE ORCHARD

Nursery	Variety	Number Planted	Number Died	Per cent Died
A	Napoleon and Black Tartarian	98	91	93
B	Napoleon and Black Tartarian	100	7	7
C	Schmidt.....	89	3	3
D	Napoleon and Black Tartarian	100	68	68
E	Yellow Spanish	91	0	0

Ninety-three per cent of the trees from nursery A and 69 per cent from nursery D, died—the various cording, trenching, pruning, and paraffining treatments having no consistent effect on lessening the degree of injury. On the other hand, only 7 per cent of the trees from nursery B succumbed, only 3 per cent from nursery C, and none from nursery E, the storage treatments here again having no effect upon the performance of the trees. In other words, something unfortunate happened to the trees received from two nursery companies, before the stock was included in the storage test, and the storage treatments had no effect upon either the good or the poor stock.

It has been impossible to determine what was responsible for the difference in the performance of the stock received from the different nursery companies, but general observation points to two possibilities, namely, cherry leaf spot (3), and exposure during digging (1, 2, 5). The main point of this discussion must not be lost sight of, however, namely, that none of the six storage treatments altered the results appreciably.

Following this experience with nursery stock secured from commercial concerns, stock was grown under known conditions on the Station grounds and subjected to a second set of storage treatments during the winter of 1930-31. Both roses and sweet cherries were used. The cherry trees were all 2-year-old trees of the Lyons variety, 50 for each treatment, 25 on Mahaleb roots and 25 on Mazzard. The roses were hybrid teas budded on *Rosa multiflora japonica* understocks, the varieties being Los Angeles, Luxemburg, and Ophelia. All plants were well grown, kept free from foliage troubles, dug when mature, and stored promptly after the following scheme.

- I. Corded in bins.
- II. Corded in bins and tops pruned.
- III. Corded in bins and tops coated with melted paraffin.
- IV. Trenched in sand.
- V. Corded in bins and tops coated with yellow crude scale wax.
- VI. Corded in bins, and tops pruned and coated with melted paraffin.
- VII. Corded in bins, and tops coated with cold miscible paraffin (Micol 180).
- VIII. Corded in bins, and tops coated with cold miscible paraffin (Micol 2015).
- IX. Corded in bins, and tops and roots coated with melted paraffin.
- X. Stacked in bins, with roots unprotected.
- XI. Trenched in sand and tops coated with cold miscible paraffin (Micol 180).
- XII. Trenched in sand and tops coated with cold miscible paraffin (Micol 2015).

The operations of cording, pruning, trenching, and paraffining were as outlined in the previous experiment. In the coating with cold miscible paraffin, two methods were used with equal success, namely painting with a brush and spraying with a portable power paint sprayer. The latter proved well adapted to coating plants with the cold emulsified paraffin, and was used in several commercial nursery cellars on several thousand plants, the advantage being that the plants could be corded horizontally in bins with tops outward, and then rapidly coated in place by the one operation of spraying. As will be brought out later, the mechanics of operation are excellent and the material spreads well and gives a thin, inconspicuous, durable coating. The difficulty to date, however, lies with the effect of these emulsions upon the plants.

TABLE III.—THE EFFECT OF STORAGE TREATMENTS UPON GROWTH OF CHERRY TREES IN 1931

Treatment	Number Plants	Average Shoot Growth (ins.)	Average Number Growing Points	Per cent Died
I Corded in bins } Mahaleb. } Mazzard.	25 25	65.84 39.64	8.88 7.44	0.0 0.0
II Corded in bins and tops pruned } Mahaleb. } Mazzard.	25 25	40.88 38.00	7.76 7.56	12.0 0.0
III Corded in bins and tops coated with melted paraffin } Mahaleb } Mazzard	25 25	41.76 41.20	7.12 8.36	0.0 0.0 ¹
IV Trenched in sand } Mahaleb. } Mazzard.	25 25	50.16 39.72	10.36 8.40	0.0 ¹ 0.0 ¹
V Corded in bins and tops coated with yellow crude scale wax } Mahaleb. } Mazzard.	25 25	44.76 40.44	10.04 8.16	4.0 12.0
VI Corded in bins and tops pruned and coated with melted paraffin } Mahaleb. } Mazzard.	25 25	21.16 39.00	7.88 8.64	8.0 0.0
VII Corded in bins, tops coated with cold miscible paraffin (Micol 180) } Mahaleb. } Mazzard.	15 15	27.06 39.66	7.2 4.9	13.3 ² 20.0 ²
VIII Corded in bins, tops coated with cold miscible paraffin (Micol 2015) } Mahaleb. } Mazzard.	15 15	70.53 36.60	9.6 8.0	0.0 ² 0.0 ²
IX Corded in bins, tops and roots coated with melted paraffin } Mahaleb. } Mazzard.	15 15	37.06 15.46	5.8 2.0	0.6 ⁴ 73.3 ⁴
X Stacked in bins with roots unprotected } Mahaleb. } Mazzard.	15 15	4.60 0.00	0.4 0.0	93.3 100.0
XI Trenched in sand, tops coated with cold miscible paraffin (Micol 180) } Mahaleb. } Mazzard.	15 15	31.80 38.20	8.6 7.0	6.6 ² 0.0 ²
XII Trenched in sand, tops coated with cold miscible paraffin (Micol 2015) } Mahaleb. } Mazzard.	15 15	24.60 30.26	4.9 5.5	26.6 ² 0.0 ²

¹Started growth 14 days earlier than Treatment I.²Growth delayed 10 days in comparison with Treatment I.³Lenticels badly swollen and proliferated.⁴Growth delayed 21 days in comparison with Treatment I.

The results with cherry trees, given in Table III, bring out many interesting facts, the more important being: (1) Stock on Mazzard roots was more easily injured by treatment in storage than stock on Mahaleb roots; (2) cording in bins in the approved nursery man-

TABLE IV—EFFECT OF STORAGE TREATMENTS UPON GROWTH OF ROSE PLANTS

Treatment	Variety	No. Plants	Relative ¹ Vigor of Plants	No. Weak Plants	No. Dead Plants
I Corded in bins.....	Ophelia	10	58	0	0
	Los Angeles	10	39	4	0
	Luxemburg	10	33	0	3
II Corded in bins and tops pruned.....	Ophelia	10	47	0	1
	Los Angeles	10	36	3	1
	Luxemburg	10	49	0	1
III Corded in bins and tops coated with melted paraffin.....	Ophelia	10	53	0	0
	Los Angeles	10	52	0	0
	Luxemburg	10	49	1	0
IV Trenched in sand.....	Ophelia	10	19	7	2
	Los Angeles	10	43	2	4
	Luxemburg	10	—	—	—
V Corded in bins and tops coated with yellow crude scale wax....	Ophelia	10	57	0	0
	Los Angeles	10	48	1	0
	Luxemburg	10	—	—	—
VI Corded in bins and tops pruned and coated with melted paraffin	Ophelia	10	48	1	0
	Los Angeles	10	43	2	0
	Luxemburg	10	42	1	1
VII Corded in bins and tops coated with cold miscible paraffin (Micol 180)	Ophelia	10	51	0	0
	Los Angeles	10	28	7	0
	Luxemburg	10	49	0	0
VIII Corded in bins, tops coated with cold miscible paraffin (Micol 2015)	Ophelia	10	46	0	1
	Los Angeles	10	29	5	1
	Luxemburg	10	46	1	0
IX Corded in bins, tops and roots coated with melted paraffin.	Ophelia	10	47	1	0
	Los Angeles	10	50	0	0
	Luxemburg	10	—	—	—
X Stacked in bins with roots unprotected	Ophelia	10	53	0	0
	Los Angeles	10	30	4	1
	Luxemburg	10	32	2	2
XI Trenched in sand, tops coated with cold miscible paraffin (Micol 180)	Ophelia	10	42	1	1
	Los Angeles	10	44	2	0
	Luxemburg	10	34	1	2
XII Trenched in sand, tops coated with cold miscible paraffin (Micol 2015).....	Ophelia	10	43	0	2
	Los Angeles	29	29	5	1
	Luxemburg	10	29	1	0

¹Computed on a basis of 7—very vigorous
6—vigorous
5—medium vigorous

2—weak
1—very weak
0—dead

ner gave as good results as any treatment used; (3) paraffining improved neither the growth nor the stand, but actually resulted in slightly poorer growth and poorer stand in some instances; (4) trenched stock started growth early, with the consequent possibility of injury in handling; (5) stock sprayed with the two cold miscible paraffins was delayed two weeks in starting and the trees severely injured by one of the two; (6) carefully cording the stock in bins and keeping the roots covered with moistened kraut is very important when contrasted with careless cording and omitting the kraut coverage on roots; (7) pruning prior to storage resulted in dying back of the tips in storage and decreased growth; (8) paraffining both roots and tops resulted in slow starting in the field and poorer growth.

The results with roses differ somewhat from those reported for cherries, as seen in Table IV. First of all different varieties of roses are affected differently by the same treatment. *Ophelia*, for example, was least affected by any of the treatments; Los Angeles was next, and Luxemburg was most easily affected.

There are many points of interest in the table, chief among which are the following: (1) Roses stood more exposure to drying out of the roots without injury than did cherry trees, *Ophelia* being scarcely affected, although Los Angeles and Luxemburg were injured to a much greater degree; (2) paraffining the tops gave the best growth and lowest mortality; (3) paraffining both the roots and the tops resulted in satisfactory growth, quite by contrast to the results with cherry trees; (4) trenching in sand resulted in earlier starting and poorer growth in all cases; (5) pruning was not beneficial and slightly detrimental in some instances; (6) the two cold emulsions of paraffin affected the Los Angeles variety most severely, Luxemburg next, and *Ophelia* least; and (7) one of the two cold emulsions of paraffin was more harmful than the other.

PRACTICAL CONCLUSIONS

The practical applications from these experiments are: The most important consideration in storage of nursery stock is the treatment prior to placing in storage, such as growing, spraying, exposure to sun and wind during digging, and freezing of roots. Cording carefully in bins and covering the roots with moistened kraut according to the approved nursery procedure is satisfactory for cherry trees; and paraffining is of no added benefit. Roses, however, may be benefited by the additional treatment of paraffining the top—some varieties more so than others. Paraffining the roots as well as the tops of cherry trees is harmful, whereas a similar treatment of roses results in little or no dying, although it is not a recommended practice. Cold emulsions sprayed on the tops with a power paint sprayer offer a rapid and convenient method of paraffining nursery stock already corded in bins, but no particular brand of emulsified paraffin should be used until its effect upon the plants has been

determined, since some may result in severe injury. Trenching in the nursery cellar is no improvement over cording in bins, in fact, it results in early starting and resulting injury to the stock in handling.

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An Apparatus for Spraying Plants With Melted Paraffin or Other Waxes¹

By T. J. MANEY, *Iowa State College, Ames, Iowa*

THE sprayer described herewith is a device designed for use in the application of melted paraffin or other waxes of similar character to living plants. The use of paraffin as an adjunct in nut grafting was first brought to the attention of horticulturists by Morris (1). Neilson (2) in subsequent studies with this material found that in addition to its uses in grafting it also could be utilized to prevent the development of molds on nursery stored roses and other shrubs, to repel borers, to reduce injury from summer sun scald and to prevent the desiccation of transplanted fruit and ornamental trees.

Melted waxes are applied to plants either with a brush or by dipping them in the melted materials. Brushing is a slow procedure and dipping has its limitations in that only the smaller sized plants may be so handled economically. In dipping there is also the possibility of injury to the plant tissue if the melted wax becomes over heated.

One of the most effective ways to apply melted wax to a plant is by means of a sprayer and therefore the following described device was designed.

The apparatus (Plate I) consists of a section of cast iron pipe (A) 2½ inches x 18 inches threaded and capped at both ends. The top cap is fitted with an inner-tube valve stem (C) and a brass air cock (D). The ½-inch pipe fitting (B) is tapped into the upper end of the main body. (E) is a 5-inch section of capped ½-inch pipe and serves as a handle only. A ¼-inch globe valve (F) and a vermored spray nozzle (G) are fitted to ¾-inch pipe and tapped into the base cap.

The procedure in manipulating the sprayer is as follows: The wax is melted in a separate container and then poured through a funnel into (A) through pipe (B), which is fitted with an air tight cap. This fitting also serves as a handle. The air cock (D), which was open to permit air to escape, is now closed and air pressure up to 100 pounds is applied through valve (C) by means of an auto-tire pump. The wax in the main tube and in the nozzle connections is kept in a liquid condition by frequent application of the flame of a gasoline blow torch to these parts. The handle (E) should be wrapped with asbestos paper to prevent the burning of the hands while holding the sprayer.

Under a pressure of 75 to 100 pounds the liquified wax is emitted from the nozzle (G) in a cone-shaped mist-like spray. Since waxes

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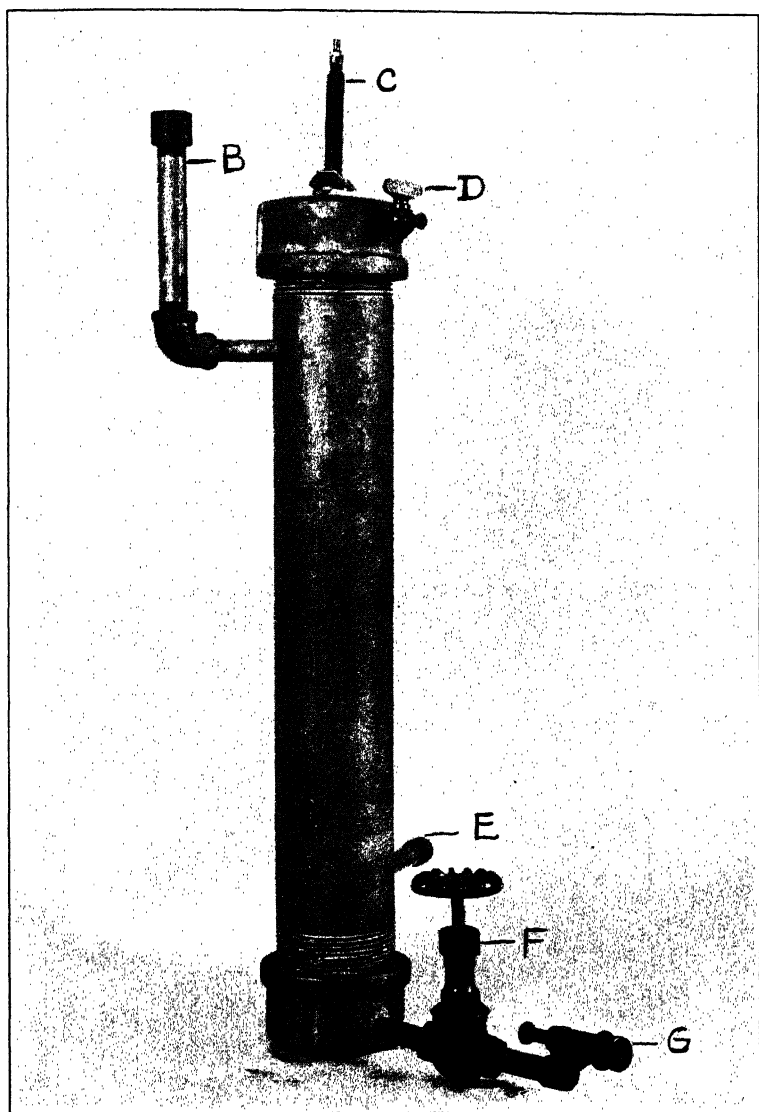


PLATE I. A sprayer designed for the application of melted waxes.

solidify very quickly, it is important to use a nozzle equipped with a disgorger.

It is recognized that the apparatus described has many defects, but crude as it is, it is the only sprayer at the present time which will handle melted waxes with any degree of success. With a little practice it can be used quite effectively. When using the sprayer in a cool atmosphere, the paraffin mist has a tendency to congeal on the plant in a fine granular condition. This defect perhaps cannot be remedied.

While the sprayer was designed chiefly for use in applying melted paraffin to common grafts and large trees, it was found to be most effective in applying a wax coating to evergreen grafts in connection with the grafting of blue spruce according to the method described by Stoutemyer (3). It is extremely difficult to brush or dip side grafts on potted evergreen stocks after the cions are set and tied, but with this apparatus melted wax may be thoroughly applied to all surfaces of the grafts and cions.

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Some Comparisons of Methods of Grafting Evergreens¹

By V. T. STOUTEMYER, *Iowa State College, Ames, Iowa.*

THIS paper describes a variation of the open bench method of grafting ornamental evergreens which should have value for commercial use and compares it with the ordinary closed case method.

Some nurserymen have been successful with closed case grafting of evergreens, but others have obtained uncertain results. A few have resorted to approach grafting, especially with the varieties of the blue spruce. However, the most desirable cion wood is often located in the terminal growths in the top of the tree where it cannot be approach grafted on potted stocks plunged in the soil. Approach grafting has the disadvantage of requiring a good supply of young trees with low branches and is not as well adapted to large scale production as bench grafting of young potted stocks.

During the first week of March, 1931, several hundred evergreen grafts were made, using blue spruce cions on Norway spruce stocks. Although the major part of the study was devoted to case grafting, the best results were secured from open bench grafting with the cions covered with paraffin. This method was suggested by the fact that a few propagators have practiced evergreen grafting successfully on open benches under closely controlled conditions of humidity. It was thought that possibly the uncertainty of both the open bench and closed case methods could be eliminated by using a protective covering for the entire cion. The well known success of Morris (1) and Neilson (2) with the use of paraffin in nut grafting suggested the trial of this material.

Ordinary paraffin with a melting point of 130 degrees F. was used. The entire scion was first dipped in the melted paraffin at 165 degrees F. Paraffin at this temperature is not injurious to the needles if the cions are dipped and cooled quickly. In no instance was there any evidence of injury to either stock or cion. Lower temperatures may be used and give a thicker coating over the needles. After the cion was cut and tied to the stock, the union was brushed with paraffin. Brushing both cion and union after the tying of the graft was also used in place of dipping, but it is somewhat slow. A device originated by Maney (3), designed to apply melted paraffin as a spray, may be used for the rapid application of this material.

Although these grafts were made during the first week of March, it is probable that an earlier date would have been advisable. They were placed on an open bench in a greenhouse which was kept at a night temperature of 55 degrees F. and no bottom heat was supplied. No attention other than an occasional watering was given. The raffia wrapping which was used for these grafts was not cut, as an accumulation of moisture under the paraffin usually caused the raffia to

¹Journal Paper No. 831 of the Iowa Agricultural Experiment Station.



PLATE I. Veneer Graft of Blue Spruce on Norway Spruce Stock



PLATE II. Completed Grafts with the Entire Cion and Union
Covered with Paraffin

disintegrate before much swelling took place. In some instances, however, there was noticeable constriction, indicating that it would be advisable to cut the raffia or to use a rubber band wrap.

These grafts on the open bench with paraffined cions and unions started to grow vigorously in a short time and formed strong unions. In a lot of fifty, 86 per cent grew. Two of the seven failures were due to death of the stocks.

TABLE I—PLAIN AND PARAFFINED EVERGREEN GRAFTS COMPARED UNDER CLOSED CASE AND OPEN BENCH CONDITIONS (BLUE SPRUCE CIONS ON NORWAY SPRUCE STOCKS)

Number in Lot	Treatment	Dead Stocks	Dead Cions	Percentage Successful Grafts
50	Paraffined grafts on open bench.	2	5	86
50	Standard closed case grafting method ²	4	11	70
25	Paraffined grafts in a closed case ^{1, 2} . . .	3	9	52

¹This lot was slow and irregular in starting.

²Complete data for the grafts in closed cases are shown in Table II.

A comparison of this method with the standard closed case grafting is shown in Table I.

The method of grafting on the open bench with paraffined cions and unions had other advantages over the closed case method than giving more good unions. No additional equipment was necessary. A minimum of attention to temperature and humidity was required. There was an entire absence of fungous infections such as often appear in the closed cases because of the heat and high humidity. The death of the potted stocks was reduced to a minimum. This method of grafting is so much simpler than case grafting that it should have commercial applications.

TABLE II—THE INFLUENCE OF WAXING AND WRAPPING TREATMENTS ON EVERGREEN GRAFTS IN A CLOSED CASE (BLUE SPRUCE CIONS ON NORWAY SPRUCE STOCKS)

Number in Lot	Treatment	Dead Stocks	Dead Cions	Percentage Successful Grafts
50	Raffia wrap.	4	11	70
50	Raffia wrap with graft union covered with paraffin.	26	10	28
50	Nurserymen's adhesive tape wrap.	7	8	70
50	Nurserymen's adhesive tape wrap with graft union covered with paraffin.	10	9	62
25	Nurserymen's adhesive tape wrap with entire cion and graft union covered with paraffin.	3	9	52

To check on the report of a nurseryman who found that a covering of paraffin over the graft wrapping hindered the union of stock and cion in closed case grafting, the treatments shown in Table II were tried. These grafts were in a closed case where an inside temperature of about 60 degrees F. at night was maintained.

In the closed case, the grafts in which the cions were entirely covered with paraffin were noticeably slow and irregular in starting, but finally 52 per cent grew. Though the results shown in Table II do not give a clear indication that covering of the union only with paraffin is detrimental in case of grafting, they show that it has no advantages over the customary practice of using an uncovered wrap.

The importance of well rooted stocks in evergreen grafting cannot be emphasized too strongly. The caliper of the trees for potting should be about $\frac{1}{4}$ inch. Young spruce trees of this size can be selected from two- or three-year old seedlings and occasionally from older lots. There is undoubtedly a distinct advantage in using freshly dug trees and potting them at once. It is important to encourage the development of new roots by careful watering after potting.

In this experiment, only trees which had formed a mass of new roots in the pots were used. Even with this precaution, it is evident from Table II that frequently the graft failures were due to the death of the stocks. The smallest loss was in the grafts which were kept on the open bench. The first evidence of stock failure usually appeared after about three or four weeks. At this time it is customary to start cutting back the tops of the stocks in order to cause a gradual diversion of the sap flow to the cions.

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The Effect of Nitrate Applications on the Soluble Carbohydrates in Apples

(SECOND REPORT)

By E. F. HOPKINS and E. W. GREVE, *Experiment Station, Wooster, Ohio*

THIS report continues one already made by Gourley and Hopkins (1) on the effect of nitrogen fertilizers on the keeping quality of apple fruits. It also continues their work (2) on the effect of nitrate applications on the soluble carbohydrates in apple fruits. They found with samples taken during the 1929 season that the application of nitrogen fertilizers had little effect on the soluble carbohydrate content of developing apple fruits.

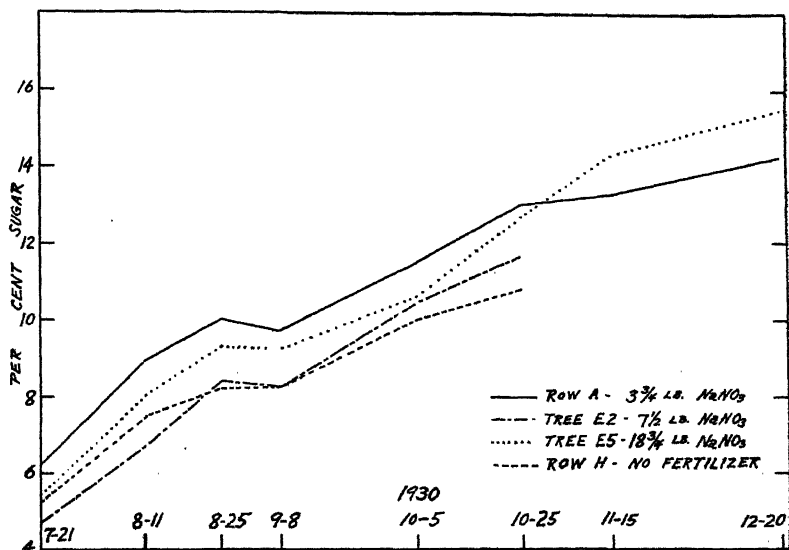


FIG. 1. Total sugar content (fresh weight) of fruits from mature Stayman trees in sod.

During the 1930 season, samples were again taken from Stayman trees growing under cultivation and in sod. The rate of application of nitrate of soda varied as indicated in Tables I, II, and III. The normal application consisted of $\frac{1}{4}$ pound of nitrate of soda for each year of the apple tree's age. Two, three, four, and five times this amount was applied in some cases. Superphosphate when used was applied at the rate of $1\frac{3}{4}$ pounds and muriate of potash at the rate of $\frac{7}{8}$ pound per tree.

In the sod orchard the unfertilized trees showed the characteristic symptoms of nitrogen deficiency. The records show that the yield of these trees has been low.

TABLE 1.—SUGAR CONTENT OF STAYMAN FRUITS DURING GROWING AND STORAGE SEASON OF 1930.
(STATED AS PER CENT ON FRESH WEIGHT BASIS)
(STAYMAN BLOCK)

Sample	Nitrate of Soda Application per Tree (Lbs.)	July 21	Aug. 11	Aug. 25	Sept. 8	Oct. 5	Oct. 25	Nov. 15	Dec. 20
Reducing Sugars									
A	3¾	6.190	8.080	8.245	7.765	8.690	8.875	8.970	9.400
E2	7½	4.680	5.475	5.930	6.125	7.385	6.915	—	—
E3	11¼	5.635	7.205	6.660	6.990	7.695	7.630	7.660	9.720
E4	15	4.880	5.815	5.700	6.255	7.730	8.275	—	—
E5	18¾	5.345	6.990	6.500	6.695	7.465	8.035	8.515	9.380
H	None	5.090	6.390	6.175	6.530	7.405	7.135	—	—
Sucrose									
A	3¾	.036	.812	1.642	1.763	2.587	3.779	3.934	4.202
E2	7½	.003	1.000	2.253	1.875	2.781	4.276	—	—
E3	11¼	.133	.979	2.446	2.117	2.996	4.024	6.373	5.779
E4	15	.426	1.485	2.490	2.649	3.237	4.240	—	—
E5	18¾	.109	.976	2.524	2.003	2.865	4.201	5.296	5.507
H	None	.136	1.147	1.844	1.569	2.365	3.289	—	—
Total Sugars									
A	3¾	6.230	8.983	10.070	9.724	11.566	13.074	13.341	14.291
E2	7½	4.683	6.597	8.434	8.208	10.475	11.666	—	—
E3	11¼	5.783	8.383	9.378	9.342	11.024	12.101	14.741	16.141
E4	15	5.333	7.465	8.800	9.198	11.316	13.208	—	—
E5	18¾	5.466	8.075	9.305	9.143	10.649	12.732	14.399	15.499
H	None	5.241	7.666	8.224	8.273	10.033	10.791	—	—

TABLE II—SUGAR CONTENT OF STAYMAN FRUITS DURING GROWING AND STORAGE SEASON OF 1930.
(STATED AS PER CENT ON FRESH WEIGHT BASIS)
(EAST ORCHARD)

Sample (Row)	Fertilizer Application per Tree	July 28	Aug. 18	Sept. 2	Sept. 15	Oct. 4	Oct. 26	Nov. 16	Dec. 21
Reducing Sugars									
1	6 lbs. nitrate of soda	5.940	7.340	6.980	7.585	8.015	8.175	8.620	9.650
3	2 lbs. nitrate of soda	6.260	7.460	7.200	8.000	8.180	8.830	8.955	9.635
5	2 lbs. N; 1 3/4 lbs. P; 1/8 lb. K	6.055	7.280	6.730	7.235	7.740	8.330	8.805	9.645
9	2 lbs. N; 1 3/4 lbs. P	6.120	7.200	7.100	7.415	7.855	—	—	—
13	2 lbs. N; 1/8 lb. K	6.260	7.825	7.360	7.390	7.750	8.265	8.770	9.055
17	None	6.205	7.540	7.220	7.680	8.130	—	8.170	9.355
Sucrose									
1	6 lbs. nitrate of soda	.602	1.631	2.175	2.182	3.181	4.222	5.722	5.730
3	2 lbs. nitrate of soda	.589	1.571	2.191	2.070	3.132	3.945	4.982	5.862
5	2 lbs. N; 1 3/4 lbs. P; 1/8 lb. K	.739	1.706	2.311	2.022	2.970	3.984	4.735	6.049
9	2 lbs. N; 1 3/4 lbs. P	.491	1.741	2.136	2.160	3.019	—	—	—
13	2 lbs. N; 1/8 lb. K	.890	1.702	2.114	1.898	2.835	3.866	4.345	5.867
17	None	1.218	1.831	2.330	2.042	2.907	—	5.111	5.867
Total Sugars									
1	6 lbs. nitrate of soda	6.009	9.152	9.397	10.010	11.550	12.866	14.956	16.239
3	2 lbs. nitrate of soda	6.916	9.206	9.634	10.300	11.660	13.216	14.591	16.148
5	2 lbs. N; 1 3/4 lbs. P; 1/8 lb. K	6.876	9.175	9.298	9.482	11.040	12.757	14.066	16.366
9	2 lbs. N; 1 3/4 lbs. P	7.066	9.135	9.473	9.815	11.210	—	—	—
13	2 lbs. N; 1/8 lb. K	7.249	9.616	9.709	9.499	10.900	12.583	13.598	15.574
17	None	7.558	9.574	9.809	9.949	11.360	—	13.849	15.874

Nightingale, Addoms, and Blake (4) found peach fruits from a high-carbohydrate tree much higher in reducing sugars and particularly in sucrose than those from a high-nitrogen tree. Gourley and Hopkins (3) working with the same trees used in the present study found that the application of nitrate of soda resulted in an

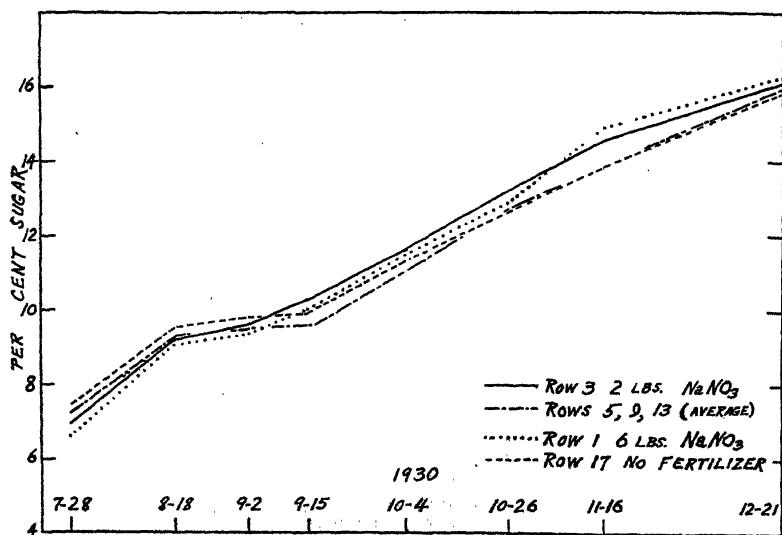


FIG. 2. Total sugar content (fresh weight) of fruits from young Stayman trees in cultivation.

increase in the percentage of total nitrogen in the fruit as well as an increase in the total amount of nitrogen per fruit. From this it might be expected that the trees receiving nitrate of soda would be lower in soluble carbohydrates than those which were unfertilized.

However, in examining the data for the Stayman Block, the orchard grown in sod, it will be noted that the percentage of reducing sugars was highest in Row A in every instance except one, that of December 20 when the results with Tree E3 were somewhat higher (Table I.) The results for the unfertilized trees, Row H, show that the percentage of reducing sugars was lower than that for Row A which received a normal application of nitrate of soda. The percentage of reducing sugars for the unfertilized trees was found to not vary much from the trees receiving excessive amounts of nitrate of soda. The values for sucrose fluctuated considerably. The fruits from Row A were found to be higher in total sugars until October 25 when Tree E4 was slightly higher. Again on November 15 and December 20, Row A was lower than either Tree E3 or Tree E5. As with reducing sugars the values for the unfertilized trees did not vary considerably from the trees receiving the ex-

cessive nitrate treatment. In general, fruit from trees receiving the normal amount of nitrate of soda was higher in reducing and total sugars than that from trees receiving excessive amounts. A possible explanation of the unfertilized row being low in these sugars is that due to the extremely unthrifty foliage the synthesis of carbohydrates was greatly reduced in comparison with the other rows where the foliage was much larger and greener.

TABLE III—SUGAR CONTENT OF WEALTHY FRUITS JUST PRIOR TO PICKING TIME, AUG. 4, 1930 (STATED AS PER CENT OF FRESH WEIGHT)
(EAST ORCHARD)

Sample (Row)	Fertilizer Application per Tree	Reducing Sugars	Sucrose	Total Sugars
2	6 lbs. nitrate of soda	8.570	.859	9.524
4	2 lbs. nitrate of soda	7.645	.986	8.740
6	2 lbs. N; $1\frac{3}{4}$ lbs. P; $\frac{7}{8}$ lb. K	8.140	1.047	9.303
10	2 lbs. N; $1\frac{3}{4}$ lbs. P	8.520	1.033	9.668
14	2 lbs. N; $\frac{7}{8}$ lb. K	8.380	.886	9.365
18	None	9.250	.909	10.260

The decrease in percentage of all sugars in some instances during the latter part of August and the first part of September may have been due to the extreme drouth which prevailed in Ohio during 1930.

In the East Orchard, the one grown under cultivation, the differences in the percentages of reducing sugars between the unfertilized and the fertilized trees was not great (Table II.) The values for sucrose fluctuated considerably. The percentage of total sugars was highest in the unfertilized row in but one instance, that of September 2. On all other dates rows treated with nitrate of soda were higher.

On August 4, a sample of the Wealthy variety was taken. The results are of interest because the percentages of total sugars and reducing sugars were higher in the unfertilized row than in any of the fertilized rows (Table III.) The values for sucrose fluctuated. Hopkins and Gourley (3) working with the unfertilized row and one of the fertilized rows in 1929 likewise found the unfertilized row to be higher in reducing and total sugars, although this difference was not large. The difference in percentage of sucrose was small.

CONCLUSIONS

From the data obtained during the 1930 season there seemed to be little if any correlation between the nitrate treatment and the percentage of soluble sugars in the apple fruits. This seemed to be true for both the cultivated and sod orchards, although the variation in percentage of the soluble sugars was greatest in the sod orchard.

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Some Effects of Preservation by Freezing on Quality of Fruits and Vegetables

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ABSTRACT

This paper will appear in full as Georgia Experiment Station Bulletin No. 168.

HORTICULTURISTS and plant physiologists have been observing the effects of preservation by freezing, as a commercial practice, on the quality of fruits and vegetables for more than 30 years. Yet due to the fact that freezing kills tissue, causes cell leakage, and destroys turgidity, freezing has long been considered a practice to be avoided, so that it has been somewhat against a prejudice that the project has developed. At present there is some difficulty in explaining how freezing is so destructive under some conditions and has such marked preservative properties under others.

Freezing as a method of preserving fruits and vegetables has been declared a success by workers in California, Georgia, Oregon, Michigan, Louisiana, Massachusetts, and Florida. The method is particularly adapted to highly-flavored, highly-colored, rather acid small fruits; but with special precaution it may be used in preserving practically all fruits and most vegetables.

Freezing causes death to the tissue of fleshy fruits and vegetables, stimulates oxidation and desiccation, and does not prevent respiration processes that result in loss of fresh flavor, aroma, and color.

Freezing and complete thawing produce some effects on fruit tissue that are similar to cooking, salting, sugaring, and drying, all of which processes cause a precipitation of cell contents and loss of juices from the tissue.

To obtain best results, frozen fruits should be eaten before or immediately after thawing. Thawing should be at as low temperature as possible.

Evidence indicates that each product has a rather definite optimum temperature at which it should be frozen and thawed.

The work here reported on mycro-physical changes in plant cells due to freezing may be summarized as follows: (1) After completely defrosting, the tissues of peach, apple, pear, plum, avocado, strawberry, blackberry, raspberry, tomato, celery, lettuce, rhubarb, watermelon, cantaloupes, and asparagus were flabby and lost from 20 to 80 per cent of their weight by leakage in 24 hours. The rate of loss was rapid at first, gradually decreasing, and reached a minimum after the 24-hour period had expired. (2) The loss of plant juices is not due to rupture of cell walls but to the irreversible precipitation of cell contents, liberating "bound water" and water which was previously within vacuoles, and was not later reabsorbed.

(3) The flabbiness or loss of structure is due to breaking down of the contents of the cells which formerly gave support to their walls. (4) The quality of water lost through cell leakage caused by freezing is very similar to that lost through leakage caused by cooking, or by placing the tissue in a saturated sugar or salt solution, when undergoing desiccation. (5) In freezing, cooking, brining, sugaring, and drying the cell contents are irreversibly precipitated and the water in the vacuoles set free. (6) Freezing at different temperatures produces slightly different effects on the cell contents but the differences are those of degree.

The quantity of fluid lost by the cell through leakage to the outside, loss of original turgidity, and degree of fragmentation of the precipitated protoplasm are in direct proportion. Using the loss of fluids as a quantitative measure of the destructive effects of the various treatments, one might list in order from least to most destructive, the following: alcohol, salt, quick freezing, sugaring, slow freezing, cooking, drying.

A Survey of Residua from Phosphorus Applications on Orchard Soils

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IT is well established by soils workers that phosphorus applied to a soil in a more or less available form is quickly "fixed." In other words, it is rapidly reverted to unavailable forms, although certain chemical and biological processes will make a fraction of it available. The degree of fixation exerted by soils depends upon the soil reaction, the amounts of aluminum and iron oxides present, the amount of calcium and magnesium, and the content of colloidal material.

As a consequence of this marked fixation factor there is little or no diffusion of phosphorus down through the soil. Bear and Salter (2) showed that even after 15 years of phosphorus fertilization, the residual effect was entirely confined to plow depth.

During the summer of 1931 a survey was conducted which included 26 Ohio orchards, one object of which was to determine the available phosphorus content of these soils. Attention was given to the distribution of available phosphorus at 1- to 2-inch levels, particularly where fertilizer experiments had been conducted by the Ohio Agricultural Experiment Station or where the previous fertilizer practices were known. This survey of phosphorus distribution in the soil profile was involved in a study of the part which this element may play in the metabolic processes in apple fruits. It also was designed to throw light upon the reasons for the frequent inability of orchardists to gain any direct benefit from phosphorus applications to fruit trees. The study also has emphasized the mechanical problem involved in supplying fruit trees with this element.

METHODS OF PROCEDURE

Holes were dug from 1 to 2 feet inside the drip of the branches, so that a profile was formed from which soil samples could be taken. Each inch-sample of soil was cut out separately from the profile to a depth of 4 inches and from 4 to 10 inches a 2-inch sample was taken. Each of these soil "slices" was well broken up and made uniform before determinations were made.

The La Motte-Truog test was utilized for determining the amounts of available phosphorus. Truog (5) describes the method as involving extraction with .002 N sulphuric acid buffered to a pH of 3.0, although the La Motte adaptation of the test involves the use of a much more concentrated acid extracting medium. Following extraction, the material is filtered, and to a measured amount of filtrate is added ammonium molybdate-sulphuric acid solution. Upon the sub-

sequent addition of stannous chloride, a blue color develops, the intensity of which indicates the amount of available phosphorus per acre.

TABLE I—PHOSPHORUS RESIDUUM IN CERTAIN PLOTS IN ORCHARD J AT WOOSTER

Soil Depth (Inches)	Pounds per Acre of Available Phosphorus ¹		
	Plot 17 No Fertilizer	Plot 9 P Plus K	Plot 13 N Plus K
0-1.....	47	98	48
1-2.....	40	61	40
2-3.....	30	45	29
3-4.....	27	45	25
4-6.....	23	37	23
6-8.....	18	25	20
8-10.....	14	18	16

¹Results express the mean of five samples from each plot.

PRESENTATION OF DATA

Orchard J at Wooster—A rather extended study was made in an orchard used for fertilizer experiments at Wooster. This orchard was planted in 1922 and the fertilizer treatments began in 1928. One-half of the orchard was cultivated for 1 year following the inauguration of the fertilizer treatments, and then in 1929 the remainder was seeded down to a mixed alfalfa-clover sod.

The various amounts of fertilizers used in 1931 were $2\frac{1}{2}$ pounds of nitrate of soda, $2\frac{1}{2}$ pounds of superphosphate, and $1\frac{1}{4}$ pounds of muriate of potash per tree in plots where these nutrients were to be applied. Each year the amounts of nitrate of soda and superphosphate have been increased $\frac{1}{2}$ pound while the potash has been increased by $\frac{1}{8}$ pound per tree.

The soil is a Wooster silt-loam. The average soil reaction in the check plots was approximately pH 4.7. Plots receiving nitrate of soda were slightly but consistently less acid.

Table I reveals the marked fixation of phosphorus and its apparent inability to diffuse very far through the soil in sod orchards. The data indicate that there is some percolation to a depth of 6 inches; this should be discounted somewhat since the single year of cultivation following the inauguration of the fertilizer treatments undoubtedly effected some mechanical distribution to that depth. The significance of the data lies in the indication of a striking fixation of the phosphorus in the surface layer. It also indicates that the most marked fixation occurs in the first inch.

W. C. Yule Orchard at Danbury—Fig. 1 indicates the results obtained in the peach orchard of W. C. Yule at Danbury where a fertilizer experiment was conducted by the Ohio Station from 1922 through 1927. The application per tree per year during the experiment was, $1\frac{1}{2}$ pounds muriate of potash, 3 pounds sulphate of am-

monia, and 4 pounds superphosphate. Since the termination of the experiment, sulphate of ammonia has been used uniformly throughout the plots.

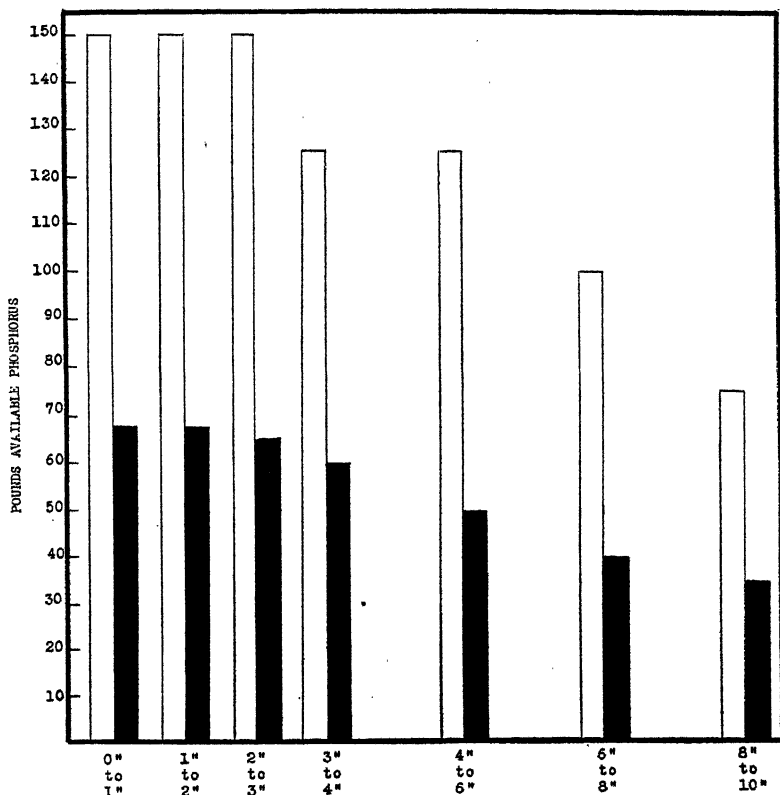


FIG. 1. Residual effect of phosphorus in a cultivated peach orchard at Danbury, Ohio. Solid bar = mean of two samples from check plot. Open bar = mean of two samples from NPK plot. (See discussion for amounts).

Phosphorus applied during the period 1922-1927. The large amounts of naturally occurring phosphorus are due to the limestone origin of the soil.

This orchard is in alfalfa with annual discing in the spring. The figure illustrates the mechanical distribution of available phosphorus in the layer affected by tillage. The discing operation has thrown up ridges in the tree row, and as a result (since some of the samples were taken in this ridged area), the figure may indicate a larger amount of phosphorus at a depth of 10 inches than might normally occur. However, it may be that due to the loose nature of the soil there is considerably less fixation and a greater possibility for penetration of applied phosphorus than in many soils.

Fig. 1 also reveals a large amount of naturally occurring available phosphorus. This is due to the limestone origin of the soil (pH 6.9).

Such soils characteristically have a higher available phosphorus content than do acid soils (4). In these soils an abundance of calcium is supplied for the formation of mono- and di-calcium-phosphates (available forms of phosphorus); and there is less fixation by iron and aluminum oxides than would occur in acid soils.

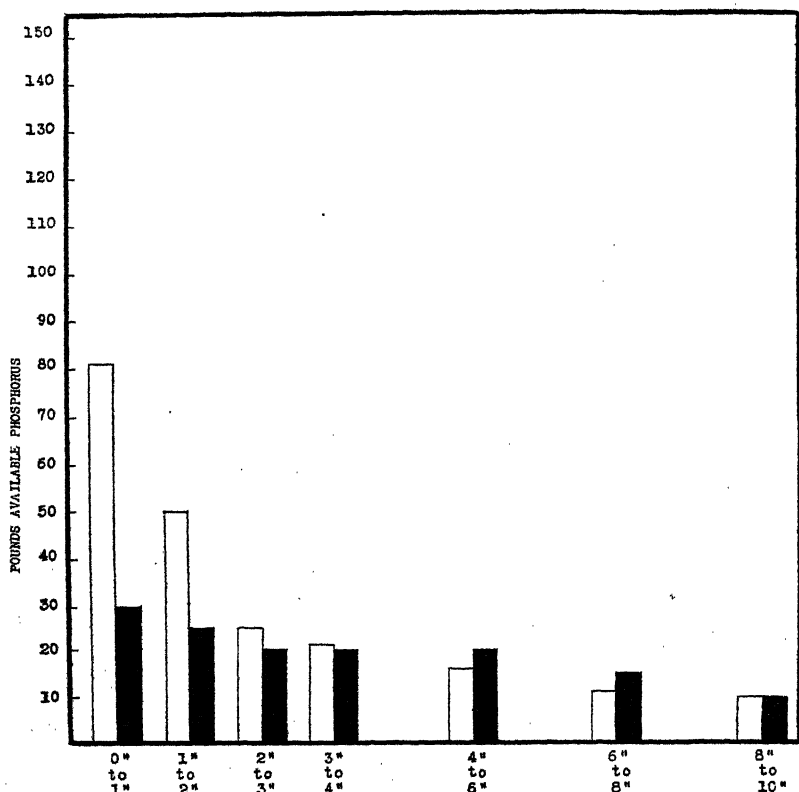


FIG. 2. Residual effect of phosphorus in a sod apple orchard, Lowell, Ohio. Solid bar = one sample from check plot. Open bar = mean of two samples from NPK plot. (See discussion for amounts).

Phosphorus applied during the period 1912-1917. Note strong residual effect after an interim of 14 years.

The data again demonstrate that there is a marked residual effect of phosphorus even after the treatments had been discontinued for 4 years.

M. H. Dyar Orchard at Lowell—Ballou and Lewis (1) conducted a fertilizer experiment in the M. H. Dyar orchard during the period 1912-1917. This is a hill orchard in southeastern Ohio. The orchard was in sod at the time of the experiment and has been so continuously.

The fertilizer treatment per tree of plot C (included in Fig. 2) was as follows: 10 pounds each of nitrate of soda and superphosphate and $2\frac{1}{2}$ pounds of muriate of potash. The treatment since the cessation of the experiment has been confined to applications of sulphate of ammonia. Ballou and Lewis (1) reported no direct benefit from phosphorus applications, but its use did result in a remarkable stimulation of the clovers in the sod.

TABLE II—PHOSPHORUS RESIDUUM IN J. F. MCCOSH ORCHARD AT VINCENT

Soil Depth (Inches)	Pounds of Available Phosphorus per Acre ¹			
	Plot 11 No Fertilizer	Plot 15 NPK	Plot 14 No Fertilizer	Plot 16 NPK
0-1.....	20	35	25	40
1-2.....	15	15	20	20
2-3.....	10	15	15	15
3-4.....	10	15	10	15
4-6.....	10	10	10	10
6-8.....	10	10	10	10
8-10.....	8	10	8	8

¹Results express the data of but one sample from each plot.

Fig. 2 indicates a most remarkable persistence of phosphorus in this orchard. After an interim of 14 years since phosphorus treatment had been made, there is still a marked residue in the first inch of soil. The clayey nature of the soil and the fact that it is extremely acid (pH 4.3) would in large part account for the strong fixing power it exerted. In plot D, in which but 5 pounds of superphosphate were used, the residue is not very marked; but undoubtedly the heavy sod in this orchard has depleted the residue of the 5-pound applications annually throughout the period of 14 years.

J. F. McCosh Orchard at Vincent—An experiment similar to that in the Dyar orchard was conducted by the Station (1) in the J. F. McCosh orchard (formerly owned by Mrs. L. E. Benedict). Half of this orchard was in cover crop-tillage culture and half in sod, but at present it is all in sod. Only the results obtained in the sod section appear in Table II. The amounts of fertilizers used per tree in the different plots were, 5 pounds each of nitrate of soda, superphosphate, and muriate of potash. Since the termination of the experiment, nitrate of soda and sulfate of ammonia have been used a few times. Ballou and Lewis (1) reported no benefit from the phosphorus applications except that they increased the yield somewhat on the cover crop-tillage section due to their stimulating effect on the growth of cover crops.

The residuum from phosphorus applications is again apparent in Table II. Where but 5 pounds of superphosphate per tree had been applied there is a substantial residue of phosphorus in the first inch of soil, even though it has been 14 years since any has been applied. This soil likewise is a yellow clay with a high degree of acidity (pH 4.2) and evidently has exerted a striking amount of fixation on the phosphorus.

Lilleland (3) recognized this problem of phosphorus fixation by soils and devised an injection rod for applying dissolved fertilizer to orchard soils under high pressure. Shade tree specialists have attacked the problem by applying fertilizers in holes about the trees. One such specialist even attempts to distribute the fertilizers mechanically in the holes by the use of compressed air. The agronomists, who have long been aware of the difficulty, have attempted to develop more satisfactory carriers of available phosphorus.

The property of phosphorus fixation exerted by soils as shown in this study, suggests a possible explanation for the frequent lack of noticeable benefit obtained from phosphorus applications to fruit trees and raises the question as to how to supply this element to them. This statement should not be interpreted as implying that phosphorus is necessarily a limiting factor in orchard production.

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Sampling Orchard Soils for Nitrate Determinations¹

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DURING the last few years a great deal has been written concerning orchard soil management and the behavior of nitrates in the soil under various treatments. A study of these papers reveals considerable variation in the results obtained by the different investigators from similar soil treatments. One investigator (9), for example, finds more nitrates in cropped soils than under clean cultivation while others (3, 6, 10) find more nitrates in clean cultivated soils. Some (11) find a depression of nitrate accumulation following the plowing under of a cover crop while others (3, 10) find a rapid increase in their accumulation. Some investigators find a decrease in the amount of nitrates during the fall (11) while others report an increase (3, 10).

There are a number of factors that may be responsible for the conflicting results obtained. First, the type of soil no doubt has an influence on the behavior of nitrates through the season. The type of soil influences the water content, the nature of the organic matter, and the organisms in the soil and thus affects the nitrate content. Second, the weather conditions influence the nitrate accumulation. Heavy rains carry the soluble nitrates to lower soil strata. Low temperatures retard whereas higher temperatures accelerate the nitrate formation. As the work was done in different parts of the country, different soil types and weather conditions no doubt will in part explain the conflicting results.

Since these factors affect the accumulation of nitrates there is no doubt but that as a result of them soil nitrates fluctuate markedly in total amounts and in their distribution in the soil strata during the growing season. This suggests a third factor influencing results obtained by investigations, namely, the frequency of taking soil samples and the depth to which taken. A brief study of the literature shows that the number of samples taken during the season varied from one (8) to twenty-two (3). The time elapsing between samples varied from 1 week (3, 6, 10) to several months. The depth to which the orchard soils were sampled varied from 6 inches to 3 feet.

The Horticultural Department of the Kansas Agricultural Experiment Station has been carrying on orchard soil management experiments for a number of years. Fig. 1 illustrates the behavior of nitrates in the top 6 inches of soil in the Station orchard during one season. The surface soil in this orchard is a silt loam and is underlaid by a heavy gravelly clay. The plot from which the data here presented were taken was clean cultivated but had 10-year-old apple trees

¹Contribution No. 107 of the Department of Horticulture.

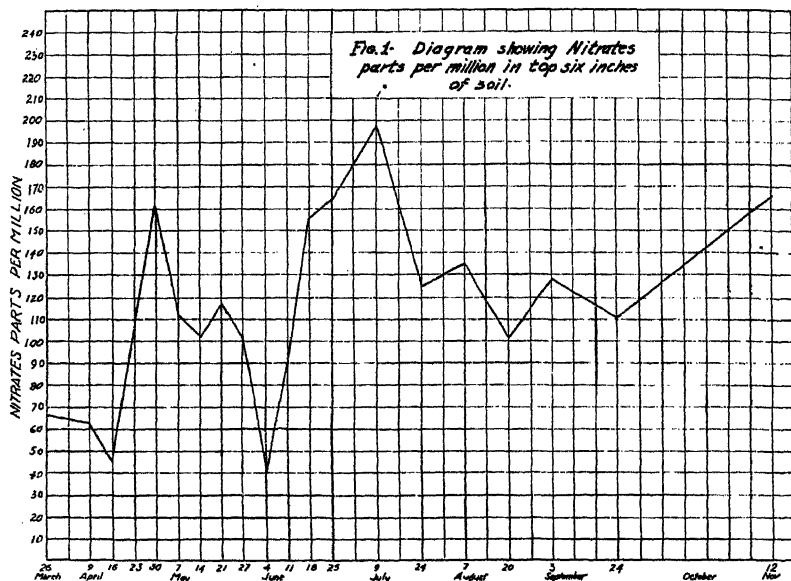


FIG. 1. Nitrates in top six inches of soil.

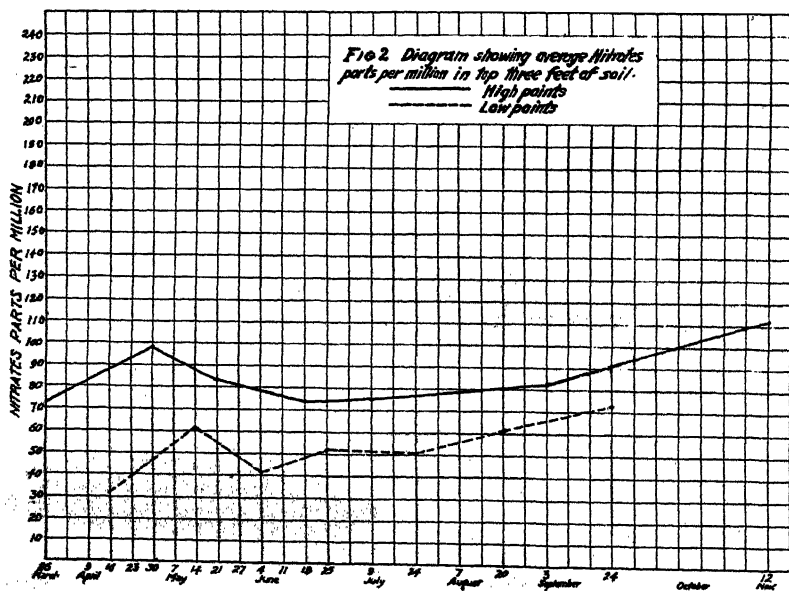


FIG. 2. Nitrates in top three feet of soil.

growing on it. Table I, on which the diagram is based, shows that the nitrates varied during the growing season from 40 to 197 parts per million.

TABLE I—NITRATES IN SOIL ON VARIOUS DATES

Date	Parts per Million	Au. Parts per Million
	In First 6 Inches	In 3 Feet
March 26.....	67	73
April 9.....	64	50
April 16.....	46	32
April 23.....	107	55
April 30.....	161	97
May 7.....	111	83
May 14.....	102	62
May 21.....	118	84
May 27.....	101	53
June 4.....	40	42
June 11.....	93	45
June 18.....	156	74
June 25.....	164	52
July 9.....	197	76
July 24.....	125	51
August 7.....	135	55
August 20.....	101	62
Sept. 3.....	129	82
Sept. 24.....	111	73
Nov. 12.....	166	112

It is evident in this case that if samples had been taken less often a very poor picture of the behavior of nitrates would have been obtained. The low points were usually preceded by rains and the nitrates leached to lower soil strata. This would lead one to believe that by taking samples to a greater depth, the amount of fluctuation would be reduced. The writer took samples to a depth of 3 feet and did find a narrower fluctuation. Table I shows that the average amount of nitrates for the top 3 feet ranges from 32 to 112 parts per million during the season. Fig. 2 is based on Table I and illustrates what could happen if soil samples were not taken at regular short intervals. One graph connects high points while the other connects low points during the same season. Should one by chance take samples only when the low points occur his results would indicate low nitrates for the season, or the converse.

It seems to the writer that, due to the many factors influencing nitrates in the soil, an investigator must take soil samples at regular short intervals of not more than a week and to a depth of 2 to 3 feet to get a true picture of the behavior of the nitrates in an orchard soil. Orchard trees are deep "feeders" and it is important to know what is happening in the soil to a considerable depth.

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Carbohydrate and Nitrogen Relationships in Apple Shoots as Influenced by Soil Management

By J. T. SULLIVAN and F. P. CULLINAN, *Purdue University, Lafayette, Ind.*

AS a part of an orchard soil management experiment, chemical studies were made over a 3-year period, on the carbohydrate and nitrogen content of the terminal shoots of Grimes apple trees, grown under tillage, alfalfa, and blue grass sod. The trees were 5 years old at the time the chemical studies were started and had been under the three systems of soil management for 3 years.

Briefly, the soil treatment which these trees had received prior to this time was as follows: During the first 2 years after planting all trees received a uniform cultural treatment, consisting of cultivation with cover crop and a spring application of $\frac{1}{4}$ pound of sulphate of ammonia per tree. After disking in the spring of the third season, two plots were seeded to blue grass, two to alfalfa, and three were left in the original treatment of tillage with cover crop. There were 20 trees in each plot. The trees in blue grass continued to receive an application of $\frac{1}{4}$ pound of ammonium sulphate for each year in age of the trees. The portions of the cultivated and alfalfa plots from which samples for chemical analyses were taken received no inorganic nitrogen fertilizer after the first 2 years.

MATERIALS AND METHODS

The material collected for analysis consisted of 1-year shoots, together with the amount of current season's growth produced at the time of sampling. Shoots were taken from 12 trees in each of the seven plots at five different periods of the year: (1) At time of terminal bud swelling, (2) 4 to 5 weeks later or petal fall stage, (3) midsummer, (4) late summer, (5) after leaf fall or early winter. The current season's growth was separated from the one-year wood, and a composite sample of 100 grams of fresh material of each of these fractions from each plot was cut into small pieces and put up in 95 per cent alcohol following the usual technique for preparing and preserving the samples. The number of trees used for sampling has been found to be sufficient to give a representative sample (2).

Determinations were made on dry weight, soluble and insoluble nitrogen, free reducing substances, sucrose, starch, and hemicellulose. The data presented here are concerned only with total nitrogen, total sugars and starch.

RESULTS

The terminal shoots of trees receiving tillage with cover crop show a greater content of total nitrogen (Table I) in per cent of dry

TABLE I.—TOTAL NITROGEN IN PER CENT OF DRY WEIGHT

Date of Sampling	Cultivation			Cultivation			Sod			Alfalfa			Cultivation			Alfalfa			Sod		
	a ¹	b ²	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
1927 Oct. 20.....	.705	.863		.703	.878		.495	.609		.910	.984		.655	.852		.598	.707		.505	.564	
1928 April 18.....	.947			.875			.653			.993			.890			.808			.668		
May 26.....	.599	1.528		.600	1.516		.461	1.152		.635	1.485		.561	1.523		.432	.633		.382	1.216	
July 6.....	.597	.807		.580	.807		.379	.575		.516	.805		.548	.783		.492	.633		.538		
Aug. 16.....	.482	.735		.486	.735		.358	.504		.434	.558		.472	.711		.364	.507		.363	.503	
Dec. 14.....	.533	.738		.535	.764		.480	.586		.593	.677		.541	.691		.559	.691		.511	.614	
1929 April 3.....	.765			.766			.592			.702			.724			.586			.619		
May 17.....	.549	1.749		.555	1.761		.464	1.580		.631	1.794		.553	1.633		.587	1.642		.481	1.632	
July 29.....	.611	.823		.591	.837		.376	.510		.511	.752		.514	.768		.457	.536		.373	.549	
Sept. 19.....	.496	.797		.478	.805		.481	.581		.454	.646		.493	.737		.405	.511		.368	.523	
Dec. 30.....	.542	.813		.505	.764		.544	.684		.540	.703		.544	.773		.519	.637		.511	.610	
1930 April 12.....	.792			.806			.719			.711			.834			.705			.644		
May 14.....	.597	1.533		.579	1.582		.556	1.544		.521	1.295		.511	1.356		.423	1.175		.440	1.312	
July 17.....	.477	.728		.474	.766		.428	.622		.420	.645		.423	.725		.373	.582		.383	.616	
Oct. 1.....	.477	.645		.482	.702		.458	.589		.524	.638		.447	.663		.404	.617		.352	.563	
Dec. 22.....	.434	.705		.475	.796		.511	.675		.547	.727		.474	.770		.473	.679		.454	.668	

¹a = 1-year wood.²b = current season growth.

weight during the growing season than trees in sod or alfalfa. The sod trees run lowest in total nitrogen in spite of the fact that they are the only trees receiving inorganic nitrogen fertilizer. The differences in total nitrogen between the various plots are much greater during the active growing season than during the dormant season. The trees in blue grass sod plus nitrogen had been under this treatment for three seasons when the first samples were taken. Terminal growth was short and the foliage was light green in color. Three years later, the sod trees showed considerable recovery in length of terminal growth and general vigor. This is reflected in the figures for total nitrogen in 1930.

In starch, (Table II) the order is reversed from that of nitrogen. The sod trees show the highest starch content and those in cultivation the lowest. The alfalfa plots fluctuate somewhat. During the growing seasons of 1928 and 1929 they are in some instances higher than sod, and in others, lower. As noted with nitrogen, the greatest differences in value for starch between various plots occur during the growing season. In the samples taken before terminal growth starts in the spring or after leaf fall, there are not such marked differences in values for starch between different plots. During the height of the growing season the terminal growth of trees in cultivation is in most instances considerably lower in starch than in trees in sod.

In total sugars (Table III), there are not such marked differences between the different plot treatments. The terminal growth of cultivated trees which was higher in nitrogen is also relatively high in total sugars. This is particularly true in the growing seasons of 1928 and 1929. In the season of 1930, which was a season of low rainfall and high temperatures, there is less difference between the plot treatments. The total sugars in 1-year wood and current season's growth show a rather general tendency over the three-year period of decreasing in value from early spring to late autumn, and then showing a marked increase in December. This is probably correlated with starch synthesis and hydrolysis. The starch values are high in autumn, showing a decrease in December.

The growth of the trees as measured by the circumference increase in trunk, prior to and during the time of sampling, is correlated with the chemical data presented. Thus, trees in tillage with cover crop which are higher in total nitrogen have made the greatest annual gains in trunk growth (Table IV). The trees in the leguminous and non-leguminous sods slowed up in growth after the plots were seeded. The terminal growth of these trees was much lower in total nitrogen during the growing season and higher in starch. Apparently the grasses competed with the tree roots in the demand for nitrogen. In the first two years following the seeding to blue grass, the trees showed small terminal growth, and very light green foliage early in the season. There was abundant moisture in the two seasons and the differences could hardly be attributed to lack of moisture. Nitrate determinations showed nitrate to be low under grass in 1927 and

TABLE II—STARCH IN PER CENT OF DRY WEIGHT

Date of Sampling	Cultivation		Cultivation		Sod		Alfalfa		Cultivation		Alfalfa		Sod	
	a ¹	b ²	a	b	a	b	a	b	a	b	a	b	a	b
1927 Oct. 20	7.15	9.05	6.36	8.95	8.75	10.85	6.82	9.84	6.34	8.64	5.93	9.06	9.02	9.78
1928 April 18	6.74	—	6.39	—	8.59	—	8.11	—	7.83	—	7.59	—	8.85	—
May 25	4.35	4.94	3.71	6.26	3.06	4.54	3.74	4.87	3.20	5.01	—	—	2.97	4.81
July 6	6.30	6.90	5.87	8.10	5.83	9.43	7.85	8.23	5.08	6.73	6.17	8.33	6.09	8.89
Aug. 16	4.75	4.82	4.53	6.11	5.76	7.45	6.26	7.15	5.48	6.00	7.67	9.14	6.10	7.86
Dec. 14	6.45	9.58	6.31	8.62	6.51	8.40	6.33	9.03	6.31	8.45	6.60	8.60	6.59	8.33
1929 April 3	7.43	—	7.73	—	8.21	—	7.04	—	7.56	—	7.62	—	7.09	—
May 17	3.80	8.59	3.30	8.94	4.12	9.99	3.40	6.88	4.04	8.76	3.84	6.97	3.64	8.25
July 29	3.87	4.38	3.32	4.30	4.40	6.42	3.64	4.62	3.97	5.08	4.22	6.97	5.33	5.69
Sept. 19	5.49	7.76	5.20	6.73	6.69	7.82	5.99	7.14	5.39	8.21	7.54	9.90	7.12	8.93
Dec. 30	5.57	7.24	5.67	6.57	5.54	6.26	5.57	6.69	5.69	7.28	6.00	6.56	5.83	6.96
1930 April 12	9.42	—	8.62	—	7.77	—	8.84	—	9.76	—	8.97	—	8.77	—
May 14	3.56	6.56	3.60	6.12	3.02	6.46	3.07	5.36	3.11	4.53	3.11	5.51	3.12	6.39
July 17	5.01	6.25	4.86	5.85	4.86	6.12	5.11	6.56	4.23	6.04	5.23	6.72	5.30	6.91
Oct. 1	7.78	9.44	7.19	8.71	7.77	8.01	8.66	11.19	8.55	10.35	8.33	9.94	8.24	10.24
Dec. 22	5.27	6.87	4.80	6.06	5.00	5.97	6.45	6.59	5.79	6.89	6.11	6.89	5.03	6.40

¹a = 1-year wood. ²b = current year's growth.

TABLE III.—TOTAL SUGARS IN PER CENT OF DRY WEIGHT

Date of Sampling	Cultivation		Cultivation		Sod		Alfalfa		Cultivation		Alfalfa		Sod	
	a ¹	b ²	a	b	a	b	a	b	a	b	a	b	a	b
1927 Oct. 20	1.08	1.54	1.04	1.54	0.95	1.18	0.97	1.57	1.03	1.55	1.00	1.37	0.96	1.26
1928 April 18	2.45	—	2.48	—	2.26	—	2.38	—	2.28	—	2.07	—	2.14	—
May 25	2.61	4.27	2.58	4.23	2.44	3.45	2.93	4.71	2.61	4.25	—	—	2.28	3.55
July 6	2.22	2.12	2.31	2.70	2.07	2.51	2.82	2.94	2.38	2.73	2.28	2.73	2.34	2.59
Aug. 16	1.59	2.23	1.63	2.33	1.48	1.77	1.58	1.88	1.43	2.10	1.37	1.56	1.32	1.55
Dec. 14	3.70	4.65	3.66	4.71	3.81	4.54	4.03	4.39	3.73	4.58	3.92	4.39	3.86	4.42
1929 April 3	3.19	—	3.32	—	2.66	—	3.06	—	3.21	—	3.05	—	2.81	—
May 17	2.71	4.71	2.73	4.74	2.23	4.26	2.73	4.59	2.82	4.85	2.44	4.05	2.23	4.54
July 29	1.42	1.71	1.38	1.88	1.28	1.66	1.43	1.91	1.66	1.90	1.35	1.51	1.48	1.71
Sept. 19	1.35	1.53	1.35	1.73	0.96	1.33	1.20	1.64	1.10	1.31	0.96	1.14	0.91	1.17
Dec. 30	3.91	5.50	3.92	5.59	3.68	4.84	3.90	5.27	3.96	5.48	3.84	4.95	3.93	5.16
1930 April 12	1.88	—	1.95	—	1.96	—	1.96	—	1.83	—	1.90	—	1.88	—
May 14	1.85	2.82	1.82	2.66	1.54	2.39	1.94	2.71	1.96	2.63	1.87	2.34	1.82	2.38
July 17	1.72	2.21	1.80	2.34	1.65	1.88	1.75	2.12	1.76	2.15	1.52	1.66	1.55	1.75
Oct. 1	1.27	1.40	1.15	1.43	0.97	1.40	0.98	1.28	1.19	1.51	0.97	1.30	1.08	1.44
Dec. 22	3.26	4.19	3.13	4.06	3.16	3.98	3.24	4.25	3.33	4.32	3.33	4.41	3.27	4.16

¹a = 1-year wood.²b = current year's growth.

1928. These 4-year-old trees had received 1 pound and $1\frac{1}{4}$ pounds of ammonium sulphate, respectively, in the two seasons. The blue grass roots had undoubtedly obtained a large share of the nitrogen.

TABLE IV—AVERAGE YEARLY CIRCUMFERENCE INCREASE IN TRUNK GIRTH PER TREE IN CENTIMETERS

Treatment	Plot	No. Trees	1926	1927	1928	1929	1930	Av. Total Gain
Cultivation.....	A	16	3.36	3.71	5.60	6.32	7.46	26.45
Cultivation.....	B	16	3.40	3.36	5.15	5.90	7.50	25.31
Blue grass sod + nitrogen	C	16	1.96	2.04	3.37	3.60	5.49	16.46
Alfalfa	D	18	2.45	3.85	4.07	4.92	5.43	20.72
Cultivation.....	E	20	3.98	3.65	5.24	6.09	6.49	25.45
Alfalfa.....	F	20	2.53	3.61	4.18	4.83	4.91	20.06
Blue grass sod + nitrogen	G	16	2.33	1.58	3.29	3.71	4.98	15.89

Results similar to these were obtained in a previous experiment (1) where trees which had been growing satisfactorily under tillage without applications of nitrogen were suddenly checked in growth when seeded to blue grass without applications of nitrogenous fertilizer. During the seasons of 1929 and 1930, the trees in grass showed recovery and made terminal shoot growth equal in length to the cultivated trees. They showed a relatively high nitrogen content in the current season's growth. However, in total size the trees in sod were much smaller. By this time the blue grass which had been cut and allowed to fall back on the ground had formed a mulch of dry grass around the tree and thus smothered out the growth of grass near the trees.

The growth of trees in alfalfa, while better than in sod, was not equal to that of trees in cultivation. The alfalfa was disked up each spring prior to 1930, but the amount of new growth produced by the plants each year did not form a good cover and reseeding was necessary to prevent bare patches in the plots. In the last two seasons, other grasses and weeds came in and the growth of the trees in 1930 was no better than that of trees under blue grass plus nitrogen. It was apparent that the alfalfa alone did not supply sufficient nitrogen for maximum tree growth. In adjacent alfalfa plots which received the same amount of nitrogenous fertilizer as trees in blue grass, tree growth was greater. A good uniform growth of alfalfa was not obtained on these plots. Results might differ under a better alfalfa cover.

At the end of the 8-year period no significant difference could be noted in the growth of trees in cultivation-cover-crop without nitrogen, as compared with other trees receiving nitrogen fertilizer in plots A and B. However, in a portion of Plot E where the unfertilized area was decidedly lower in organic matter than the unfertilized area of plots A and B, applications of nitrogen fertilizer benefited leaf color and tree growth.

A comparison between growth, chemical composition, and fruit yield cannot be made since few trees produced fruit in any of the plots before 1930. In that year the amount of bloom was scattered with more trees in the cultivated and alfalfa plots blossoming and producing fruit. In 1931, about 93 per cent of the trees in cultivation, 90 per cent of the trees in alfalfa, and 50 per cent of the trees in sod blossomed and produced fruit.

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The Nitrogen Supply for Young Apple Trees Growing in Leguminous and Non-Leguminous Sod

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IF the lack of available nitrogen under grass is primarily responsible for the relatively poor growth and productivity of apple trees grown in sod, it would be reasonable to expect that the use of a legume, such as alfalfa, would be less harmful than grass or weeds (1). It needs to be determined, however, to what extent the nitrogen requirements of apple trees can be met by a legume which is not plowed under but which is handled as a more or less permanent sod. The experiment discussed in this paper has been planned in part to shed more light upon the questions involved.

In the spring of 1928, a block of 3200 apple trees was planted at the Cornell University Orchard, Ithaca, N. Y., on land previously used for a succession of farm crops. A red clover sod was plowed under in the fall previous to planting. The trees were set at 10 ft. intervals in rows 10 ft. apart. In each of the 40 odd-numbered rows, five different varieties were planted in rotation so as to have each variety in several different parts of the row. In every even-numbered row a single variety was used throughout to serve as a buffer and to indicate soil variations occurring at 10 ft. intervals. The trees were pruned to a standard pattern at the time of planting, but no pruning has been done since that time.

During the first part of the growing season of 1928, the entire experimental area was frequently cultivated until the latter part of July. The area was then divided into five rectangular plots, each of which contained 16 rows of 40 trees each. After making liberal applications of lime and superphosphate, these plots were seeded respectively to alfalfa, rye, grass, alfalfa, and grass. A good stand was obtained in all cases.

The program of soil management for 1929 and 1930 was as follows: (1) Cultivation cover crop area—plow the rye cover crop in April; cultivate to keep down weeds until July; sow cover crop, rye 1929, sweet clover 1930; (2) Alfalfa and grass plots—mow early in June, pile fresh clippings in circle 5 ft. in diameter about the base of all trees in the plots; mow these plots again in August and allow clippings to rot in place.

The procedure in 1931 was varied somewhat. Only half of the cultivation-cover-crop plot was plowed and cultivated in the usual manner. The sweet clover was allowed to grow on the other half of this plot. The east and the west thirds of the plots in grass, in alfalfa and in sweet clover were mown on June 10, allowing the clippings to rot in place. The middle third of each of these areas remained undisturbed until early August when the alfalfa and sod plots were again mown and when the sweet clover was disked

under. A cover crop of rye was sown at this time on the entire cultivated plot as originally planned.

Fertilizer was applied in a circle 4 to 5 ft. in diameter around each tree in every other row, not counting the buffer row, as follows: June 1, 1929, $\frac{1}{2}$ -pound sodium nitrate; June 1, 1930, $\frac{1}{2}$ -pound sodium nitrate; May 15, 1931, 1 pound ammonium sulphate.

RESPONSE OF TREES

During the first year when the soil management was the same throughout the area, the trees grew well and the soil variations which affected tree growth proved to be about equally distributed among the plots. During 1929 and 1930, the trees on the cultivated and on the alfalfa plots, with and without nitrogen, showed about the same leaf color, and differences in vigor could not be ascribed to the treatments. During the season 1931, however, there was a slightly darker green leaf color on the trees in alfalfa which received nitrogen compared with those receiving no fertilizer.

In the sod plots, those rows receiving nitrogenous fertilizer, as was to be expected, were obviously superior to the non-nitrated rows in leaf color and vigor even as early as the summer of 1929. The differences became even more noticeable in 1930 and 1931. In general, the leaf color and vigor of growth of the sod trees receiving nitrogen compared favorably throughout the 3-year period with trees under cultivation and alfalfa.

In 1931 the leaves of the trees on those parts of the alfalfa and grass plots not mown until August were noticeably lighter green as compared with the foliage of the trees where the grass and alfalfa was cut in June. This difference was less striking in late fall but persisted longest in case of the non-fertilized grass. On the other hand, in the cultivation-cover-crop area, the foliage of the trees was as good where the sweet clover was allowed to mature as that on parts of the plot where sweet clover was cut in June, or for that matter, where the cover crop had been plowed under in spring. Cutting of the sweet clover was done too late to force a second growth of clover from the basal buds and the soil condition was such that a luxuriant growth of weeds, mainly foxtail (*Silaria glauca*), took possession of the soil along with the sparse second growth of sweet clover. Soon after cultivation ceased on the plowed portion the weeds likewise came up abundantly.

GIRTH MEASUREMENTS

Girth measurements of the tree trunks were taken at the end of each year and the averages for 1931 for the various varieties under different treatments are given in Table I. While the differences may seem small, it should be noted that the relatively large number of trees involved in each plot greatly reduces the probable error. Furthermore, approximately the same differences were shown when the 4 to 12 trees of each variety in each row were regarded as separate

plots. It is well known that small differences in girth of young trees indicate rather large differences in total growth of the trees.

TABLE I—GIRTH OF YOUNG APPLE TREES UNDER CULTIVATION, IN ALFALFA AND IN GRASS SOD WITH AND WITHOUT NITROGEN FERTILIZER ADDED

Variety	No. Trees Receiving Each Treatment	Average Girth in Centimeters					
		Cultivation Cover Crop		Alfalfa		Sod	
		—N.	+N.	—N.	+N.	—N.	+N.
Cortland.....	96	13.3	13.3	12.6	13.1	11.7	13.5
Delicious.....	32	13.1	14.1	13.4	14.0	13.5	15.0
Rhode Island Greening.....	96	15.6	16.2	15.2	16.1	14.3	16.5
McIntosh.....	32	13.3	13.5	13.3	13.9	11.7	14.0
Northern Spy...	64	13.7	14.2	13.6	14.3	11.5	14.3

In the main, the girth measurements correspond to the observations of leaf color and general vigor. The sod trees without nitrogen have made the poorest growth, excepting the variety Delicious. All varieties, excepting Cortland, made as good growth under alfalfa as under cultivation where no nitrogen was added.

Where nitrogen was used, the trees under cultivation, in alfalfa, and in grass all show approximately the same girth for a given variety. If there is any difference, it is slightly in favor of the grass trees. This may be due to the fact that the grass responds more than does alfalfa to nitrogen applications. It is known that nodule production on legumes is greatly reduced by heavy applications of nitrogen and this may explain why the growth of alfalfa is about as good whether or not nitrogen fertilizer is used (2). During the earlier years when the clippings were piled around the trees, the grass mulch smothered the surface growth for a longer period than did the alfalfa mulch. The fact that the alfalfa under the mulched circle around the trees was soon killed and replaced by grass should also be considered in interpreting the results.

SOIL MOISTURE CONDITION

In 1931 the rainfall at Ithaca, during the months from April through August, was 11 inches, or approximately two-thirds the mean for that period. It seemed that under these conditions the soil moisture differences in the various plots would be especially marked. The average moisture content of the surface foot of soil in a large number of samples obtained from the spaces between the trees is shown in Table II. Where the grass and alfalfa were cut in the early part of the summer, the soil moisture is somewhat higher than in any other case. The low moisture content on the cultivated plots may be explained on the basis of the luxuriant growth of the volunteer crop of weeds which took possession of the land after cultivation ceased in early July. Since the growth of the trees in the cultivated plots was as satisfactory as in other plots, it is obvious that the variations in tree growth observed in

this experiment are not closely related to the differences in soil moisture content. The ability of the trees to use the available moisture apparently depends to a large extent upon the nitrogen supply in the tissues of the trees.

TABLE II—SOIL MOISTURE CONTENT, AUGUST 6, 1931, IN PLOTS VARIOUSLY TREATED

Soil Management	Moisture Per cent of Dry Weight
Alfalfa—Cut, June 10.....	18.2
Not cut.....	15.7
Grass—Cut, June 10.....	18.1
Not cut.....	16.8
Sweet Clover—Plowed under June 10. Good stand of weeds, mostly Foxtail (<i>Silaria glauca</i>).....	12.7
Sweet Clover—Cut, June 10. Soil covered by mixture of Foxtail and second growth clover.....	16.8
Sweet Clover—Not cut. Good stand 5 to 7 ft. tall.....	15.6

TABLE III—NITROGEN CONTENT OF TWIG LEAVES OF YOUNG APPLE TREES GROWING UNDER CULTIVATION, IN ALFALFA, AND IN GRASS SOD WITH AND WITHOUT NITROGEN FERTILIZER ADDED

Variety	Date of Sampling	Nitrogen in Per cent of Dry Matter					
		Cultivation Cover Crop		Alfalfa Seed		Grass Sod	
		—N	+N	—N	+N	—N	+N
Cortland.....	Oct. 10, 1930	—	—	1.71	1.93	1.39	1.84
	June 9, 1931	—	—	2.38	2.77	1.98	2.75
Delicious.....	Oct. 10, 1930	—	—	2.20	2.60	1.69	2.14
	June 9, 1931	2.51	2.92(a)	2.37	2.82	1.93	2.74
		2.60	2.69(b)				
	Oct. 17, 1931	—	—	1.93	2.08	1.81	2.11
Rhode Island Greening.....	Oct. 10, 1930	—	—	1.88	2.20	1.86	2.30
	June 9, 1931	—	—	2.37	2.82	1.67	2.52
McIntosh.....	Sept. 29, 1930	—	—	—	—	1.58	2.16
Northern Spy...	Oct. 10, 1930	—	—	1.93	2.20	1.69	2.11
	June 9, 1931	2.49	2.90(a)	2.14	3.00	2.05	2.79
		2.64	2.87(b)				
	Aug. 10, 1931	2.34	2.62(a)	2.00	2.45(c)	1.78	2.28(c)
		2.14	2.51(b)	2.42	2.51(d)	1.92	2.45(d)
	Oct. 17, 1931	—	—	2.01	2.14	1.58	2.08

a-b. Sweet clover cover (a) Plowed under in spring; (b) Still growing; (c) Sod mown, Aug. 7, (d) Sod mown, June 10 and Aug. 7.

NITROGEN CONTENT OF THE TISSUES

Chemical analyses have been made to determine the nitrogen of the leaves, of the bark, and of the wood. In this paper the results for the leaves will be given special consideration. Samples of

leaves, chosen approximately 6 inches from the base of representative terminal shoots, were taken from 20 trees of each varitey for each treatment. Total nitrogen was determined in the dried leaves according to the official methods.

Where no nitrogenous fertilizer was added to the soil, the nitrogen content of the leaves of apple trees growing in grass was the lowest of any of the plots, while those from trees in cultivation were highest. The leaves from trees on alfalfa plots occupied an intermediate position, indicating that alfalfa alone, even though superior to unfertilized sod, does not supply as much nitrogen as the trees can obtain in the cultivated soil. It should also be noted that the apple trees are apparently able to obtain more nitrogen under vigorously growing sweet clover than under a good stand of alfalfa.

Under the conditions of this experiment the addition of fertilizer increased the nitrogen content of the leaves of trees growing in cultivated plots, and the girth measurements likewise indicated a favorable response in growth. While the trees in grass with nitrogen applied showed a somewhat lower nitrogen content in their leaves than was found in either the fertilized alfalfa sod or the fertilized cultivation-cover-crop plots, nevertheless this difference was not reflected in the girth of the trees. These results suggest that the nitrogen content of the leaves of the fertilized trees in the cultivation-cover-crop plots and in the fertilized alfalfa probably exceeded the optimum amount.

In June, the nitrogen content of apple leaves was as high or even higher where the sweet clover was still growing as it was on parts of the cultivated area with the legume turned under in early spring. As previously indicated, where cultivation stops in early July the moisture content available during the latter part of the growing season was greater under the sweet clover than under the volunteer crop of weeds which appeared after cultivation ceased. The increasing popularity of sweet clover as a biennial cover crop therefore appears to be well founded.

The somewhat lower nitrogen content of the leaves in the October samples as compared with the samples taken in June is a reflection of the influence of aging leaves and suggests also that the movement of nitrogen into the twig may have begun. The determination of nitrogen during the latter part of November in the bark of 3-year-old branches about 2 centimeters in diameter shows a percentage approximately two-thirds as high as that found in the leaves during October. The relationships to the various soil treatments is the same as shown by the data for leaves. In the wood, the percentage of nitrogen is approximately one-fourth as great as that of the bark, and here, too, the sod plots show least, while cultivation-cover-crop plots show the highest amount. In contrast to the other tissues, however, the percentage of nitrogen in the wood is slightly less where the nitrogen is added to the soil than in the corresponding treatments without fertilizer. Studies on carbo-

hydrate, which are to be reported in detail elsewhere, indicate that nitrogen application increases the amount of starch stored in the wood to a much greater extent than it increases the amount of starch stored in the bark.

CONCLUDING REMARKS

It is apparent that the use of alfalfa as a permanent cover of the orchard soil affords a better nitrogen supply for apples than is available under grass, and the growth of young trees is approximately as good as under cultivation. On the other hand, alfalfa alone does not supply all of the nitrogen that the trees can use. Where a nitrogenous fertilizer is applied to the alfalfa there is some increase in the nitrogen content of apple tree tissue, but so far as growth is concerned, there is no greater benefit than that obtained by applying fertilizer to the grass sod. Sweet clover comes nearer than does alfalfa to supplying as much nitrogen as is released by cultivation alone.

Where the cultivation ceases early in the growing season, the nitrogen available to the apple tree, especially in late fall, may be reduced by a rapidly growing non-leguminous cover crop. Under such conditions the nitrogen supply can be maintained at a high level by the application of fertilizer, or by continuing cultivation later in the season.

It is evident that much of the nitrogen is locked up in the tissues of either the alfalfa or the grass and therefore early and frequent mowing seems advisable if the maximum amount is to be made available to the tree in spring. It may be desirable to cut the grass or alfalfa as soon as it is high enough to be clipped by the mower—in early May, if possible. The nitrogen content of the young succulent clippings is relatively high, and it is evidently in a very easily decomposed form so that it becomes available to the trees within a few weeks. Where the grass or alfalfa is cut less frequently and at a more mature stage, the nitrogen is, of course, withheld from the tree for a longer period, but the amount of dry matter which serves as a mulch is greater. Unless it is piled in a small area, however, the mulch will seldom be heavy enough to smother the surface growth, and in all probability more soil moisture would be conserved by frequently reducing the transpiring surface of the sod, as is done by mowing. Furthermore, the better nitrogen supply under the clipped sod will enable the trees to utilize more of the moisture available in a relatively dry soil.

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Nitrogen Intake and Translocation in Apple Trees Following Fall, Winter and Spring Sodium Nitrate Applications¹

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IN some fruit regions it is a commercial practice to apply a quickly available nitrogenous fertilizer in the fall as well as in the spring. The fall nitrate, usually applied in late September, has resulted in satisfactory growth responses of the tree. The experimental work of Hooker (3, 4) and Schrader and Auchter (5, 6) has shown the spurs of trees receiving nitrate in the fall to be higher in total nitrogen the following spring than spurs of unfertilized trees. Furthermore, one year at blossoming time Schrader and Auchter (5) found more total nitrogen in the spurs of trees receiving nitrate in the fall than in the spurs of trees receiving nitrate in the spring, and the next year at blossoming time they (6) found nearly as much total nitrogen in the spurs of fall fertilized as in the spurs of spring fertilized trees. These results show that by spring the nitrogen from early fall nitrate applications reached the spurs, but they do not show whether the nitrogen from the fall nitrate remained in the soil during the winter to be taken up by the tree in the spring, or whether the nitrogen was taken up by the tree in the fall.

In regions of relatively mild winters, such as the Shenandoah-Cumberland region, only a few inches of surface soil are frozen during the coldest weather, and for many periods the soil is unfrozen. Thus many of the apple tree roots should be sufficiently active during the late fall and winter to take up available nitrogen. To study the nitrogen intake and translocation in apple trees following fall, winter, and late spring nitrate applications a series of experiments have been carried on during the past 3 years. It has already been shown (1) that nitrate applied in late August or early September increased, in some cases, the nitrogen content of the spurs and leaves within 4 to 6 weeks. Unpublished data have shown that when the nitrate was applied in the late fall or in the winter, the nitrogen content of the spurs was usually not increased, until growth had commenced the following spring, but at that time the spurs of late fall and winter fertilized trees had nearly as much nitrogen as the spurs of early fall or spring fertilized trees. Since it was found that occasionally late fall or winter nitrate

¹These experiments were started and conducted for two years as a Maryland Experiment Station problem under the direction of Dr. E. C. Auchter. The third year's work, reported in this paper, was conducted as a joint problem between the Maryland Experiment Station and the U. S. Department of Agriculture.

applications did result in increased spur nitrogen during the fall and winter, as compared with the check, it seemed likely that nitrogen was taken up during the winter months. To secure more data upon nitrogen intake by the tree during the winter, an intensive study was made of a few trees receiving either late fall, winter, or spring nitrate applications.

OUTLINE OF METHODS

Small, nitrogen-deficient York Imperial apple trees near Hancock, Md., about 10 years old and in the off-bearing year were used. The trees had previously received no fertilizer except a very light application of manure during the previous winter. The soil was poor, a shallow Holston loam, low in organic matter, with only a few weeds growing upon it.

Eight groups of three trees each were selected, each in one of eight parallel rows extending up a gradual slope. The York Imperial rows alternated with Oldenburg rows, which served as buffers. Groups E and F, left unfertilized, are referred to as "check groups." Groups C and D received 10 pounds of sodium nitrate per tree on Nov. 1, 1930, groups G and H, 10 pounds on Jan. 1, 1931, and groups A and B, 10 pounds on March 5, 1931. Just before applying the nitrate and at intervals thereafter samples of very small rootlets, medium-sized roots, terminals, and spurs were obtained for analysis.

The root samples were taken from the first foot of soil in four places around each tree in each group. After the roots were thoroughly washed and surface-dried, the very small rootlets (under 0.5 mm. in diameter) were removed from the large root pieces, and constituted the "rootlet" sample. From larger roots between $\frac{1}{8}$ and $\frac{1}{4}$ inches in diameter, representative pieces were cut, constituting the "medium-sized root" samples. A terminal sample consisted of a composite of 18 shoots secured by taking six terminal shoots (5 to 7 inches long) from each of the three trees in each group. On May 15, 1931, sampling, the terminals were separated into "1930 growth," "1931 growth," and "leaves." A spur sample in the dormant season included the 1930 growth of 30 non-blossoming spurs from each tree in each group. At the May 15 sampling only spurs having just three fully developed blossoms were used, and each spur was separated into "1930 growth" and "1931 growth" and the 1931 growth was further separated into "wood," "leaves," and "blossoms." These samples were dried at 70 degrees F. for 72 hours, ground and analyzed for total nitrogen by the Gunning-Kjeldahl method, as previously described (1).

RESULTS OBTAINED

Rootlets—The total nitrogen content of the rootlets is given in Table I. Between November 1 and January 1 the nitrogen in the

rootlets of groups C and D, which were fertilized with nitrate on November 1, increased over 50 per cent; whereas in the check groups the rootlet-nitrogen increased only 4 and 16 per cent, respectively. Between January 1 and May 15 the rootlet-nitrogen of groups C and

TABLE I—THE TOTAL NITROGEN CONTENT OF YORK IMPERIAL APPLE ROOTLETS (UNDER 0.5 MM. IN DIAMETER) FOLLOWING SODIUM NITRATE APPLICATIONS (10 LBS. PER TREE) IN LATE FALL, IN MID-WINTER, AND IN EARLY SPRING

Dates Samples Were taken	Nitrogen Expressed as Per cent of Dry Weight							
	Trees Receiving Nitrate on March 5, 1931		Trees Receiving Nitrate on November 1, 1930		Trees Without Nitrate Check		Trees Receiving Nitrate on January 1, 1931	
	Group A	Group B	Group C	Group D	Group E	Group F	Group G	Group H
Nov. 1.	—	—	1.02	1.09	1.14	1.10	—	—
Jan. 1.	—	—	1.64	1.56	1.19	1.28	1.36	1.30
March 5.	1.29	1.33	1.69	1.64	1.23	1.26	1.75	1.77
April 15.	1.50	1.61	1.71	1.78	1.45	1.29	1.71	1.73
May 15.	1.50	1.66	1.76	1.53	1.51	1.36	1.74	1.65

D continued to increase but at a very slow rate. The rootlet-nitrogen of the check groups E and F also continued to increase at a rate greater than in the fall fertilized groups. Thus while the rootlets of the unfertilized trees took up nitrogen slowly all winter and spring, similar rootlets of the fall fertilized trees absorbed much nitrogen during the 2 months following the fall nitrate application.

The rootlets of groups G and H, receiving nitrate on January 1, increased in nitrogen approximately 30 per cent between January 1 and March 5; whereas the rootlets of the check groups showed very little nitrogen increase during that period. After March 5 the winter fertilized groups showed no further increase in rootlet-nitrogen. In this case the rootlets of winter fertilized trees took up a great deal of nitrogen during the 2 coldest months, January and February.

The rootlets of groups A and B, receiving nitrate on March 5, increased in nitrogen 16 and 21 per cent, respectively, between March 5 and the commencement of the growth on April 15; whereas the rootlets of the check groups E and F increased in nitrogen 18 and 2 per cent, respectively. By the time growth was beginning the rootlets of these spring fertilized groups had not shown nearly as great a nitrogen increase as compared with the check as had the rootlets of both the fall and the winter fertilized groups since receiving their nitrate applications. However, nitrogen may have been moving out of the rootlets of the spring fertilized trees faster than out of the check rootlets, thus masking the nitrogen intake by the roots of these fertilized trees. The data upon the medium-sized roots presented next indicates this translocation out of the rootlets. The rootlet data have shown that nitrate applied in the late fall, in mid-winter, or in

the early spring resulted in increased nitrogen in the very small roots within 6 to 8 weeks, as compared with the check.

Medium-Sized Roots—Space does not permit the presentation of full data on the total nitrogen content of the medium-sized roots ($\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter). These roots of the fall fertilized groups C and D increased in nitrogen 22 and 38 per cent, respectively, between November 1 and January 1; while that of the check groups decreased during this time. These data indicate that part of the nitrogen taken up by the rootlets of the trees receiving nitrate was translocated to the larger roots; but in the unfertilized trees nitrogen was moved out of the larger roots faster than it was moved in from the rootlets. The medium-sized roots of the fall fertilized groups continued to increase in nitrogen until March 5, and decreased in nitrogen when growth of the tops commenced. The nitrogen in medium-sized roots of the check groups decreased until March 5, and thereafter remained fairly constant.

In the groups receiving nitrate in the winter, the nitrogen of the medium-sized roots of group G remained constant between January 1 and March 5; whereas the nitrogen of similar tissue of group H increased. By April 15 the nitrogen in the medium-sized roots of both winter fertilized groups G and H had increased considerably, but after April 15 the nitrogen in this tissue of group H decreased.

The medium-sized roots of groups A and B receiving nitrate in the spring, increased in nitrogen between March 5 and April 15. After April 15 the root-nitrogen of group A continued to increase while that of group B decreased.

These data indicate that during the winter nitrogen taken up by the small rootlets was translocated into the larger roots, and that this translocation continued during the 3 to 4 winter months following a fall or winter nitrate application. In the medium-sized roots of the unfertilized trees the nitrogen was apparently moved out into the other parts of the tree faster than it was moved in from the absorbing rootlets. In the fertilized trees although the nitrogen was probably also moving out of the medium-sized roots, the total nitrogen increased during this period in three out of four groups. The fact that on May 15, at full bloom, the medium-sized roots of the groups receiving nitrate were higher in nitrogen than such roots of the unfertilized groups indicates that these larger roots function at this time as storage tissues.

The fact that medium-sized roots from the unfertilized trees decreased in nitrogen content during the winter indicates that in the case of all trees there was some movement of nitrogen out of the larger roots into other parts of the tree during that time. In order to determine whether this nitrogen was translocated to the buds and shoots before the commencement of growth the data upon the terminals and spurs were secured.

Terminals—The nitrogen in the terminals of the unfertilized trees increased slowly during the winter and then increased rapidly just

before growth commenced on April 15. By May 15, when the trees were in full bloom, much of the nitrogen had moved out of the old (1930) growth into the new growth and leaves.

TABLE II—THE TOTAL NITROGEN CONTENT OF YORK IMPERIAL APPLE SPURS¹ FOLLOWING SODIUM NITRATE APPLICATIONS (10 LBS. PER TREE) IN THE LATE FALL, IN MID-WINTER, AND IN EARLY SPRING

Dates When Samples Were Taken	Nitrogen expressed as per cent dry weight							
	Trees Receiving Nitrate on March 5		Trees Receiving Nitrate on November 1		Trees Without Nitrate Check		Trees Receiving Nitrate on January 1	
	Group A	Group B	Group C	Group D	Group E	Group F	Group G	Group H
Nov. 1	—	—	1.54	1.49	1.41	1.40	—	—
Jan. 1	—	—	1.48	1.61	1.56	1.56	1.56	1.57
March 5	1.51	1.54	1.64	1.58	1.51	1.60	1.52	1.59
April 15	2.56	2.56	2.51	2.55	2.49	2.56	2.51	2.36
May 15								
1930 Growth.	1.60	1.65	1.55	1.52	1.45	1.45	1.68	1.84
1931 Growth.	3.54	3.40	3.47	3.37	3.23	3.27	3.80	3.96
1931 Leaves.	3.33	3.37	3.40	3.17	2.93	3.10	3.50	3.70
1931 Blossoms	3.57	3.53	3.43	3.43	3.27	3.07	3.77	3.97

¹Note—The spurs taken at the first four samplings were those which had not blossomed the previous spring but which apparently would blossom the current spring. Spurs taken May 15 were those having three blossoms per cluster.

The terminals of groups receiving nitrate on November 1 and January 1 showed approximately the same nitrogen changes as the terminals of the check groups until March 5. On March 5 the fall and winter fertilized groups failed to show a significant terminal nitrogen increase as compared with the check groups. Between March 5 and April 15 all fertilized groups and both check groups showed marked increases in terminal-nitrogen, with the terminals from the fertilized groups showing in most cases slightly more nitrogen on April 15 than the terminals of the check groups. On May 15 the 1931 terminal growths of all fertilized groups had slightly higher nitrogen contents than those of the check groups. The leaves on the 1931 terminal growths of the fertilized groups were much higher in nitrogen than the leaves of the check groups.

These data show that on the average nitrate applications in the fall or in the winter did not result in significant nitrogen increases in the terminals by March 5, as compared with the check. By April 15, when the terminals of all trees were increasing in nitrogen just at the commencement of growth, the terminals of all groups receiving nitrate had nitrogen increases resulting from the nitrate applications, although the increases over the check were very slight. This would indicate that the nitrogen translocation from the storage tissues to the terminal growing points did not take place to any great extent until growth started.

Spurs—The nitrogen content of the spurs is given in Table II. None of the groups receiving nitrate in the fall, in the winter, or in the early spring showed significantly higher nitrogen in the spurs before or on the April 15 sampling. On the May 15 sampling, however, all the groups receiving nitrate showed higher nitrogen content in the new and old growths, leaves and blossoms than did similar tissue in the check groups. The highest nitrogen content was found in the spurs from the January 1 fertilized groups.

These data bring out the fact that, although the roots took up nitrogen from the fall, winter, and spring nitrate applications within 6 to 8 weeks after the nitrate was applied, the total nitrogen content of the spurs was not affected until the new spur growth was developing.

DISCUSSION

The increase in total nitrogen during the winter in the feeding rootlets of these nitrogen-deficient trees indicates that these roots were taking up nitrogen from the soil. Sullivan and Kraybill (7) concluded, from their work with Stayman Winesap in Indiana, that absorption of nitrogen from the soil took place during the winter. The decrease during the winter in total nitrogen in the medium-sized roots of the check trees found in the present work indicates the movement of nitrogen out of these roots faster than it moved in. Since Eckerson (2) has shown the presence of reducase (nitrate reducing material) in apple roots during the winter, the nitrogen in the roots may be reduced during the winter from the nitrate to the organic forms of nitrogen. Such data all point to active nitrogen movement and metabolism in apple roots during the winter months.

The fact that on March 5 the terminals and the spurs of the fall or winter fertilized trees did not show appreciable nitrogen increases as compared to similar tissue in the unfertilized trees indicates that the increased nitrogen taken in by the roots following fall or winter nitrate applications was in this case not translocated to the growing points of the limbs during the winter. Although the root data show that part of the nitrogen from the nitrate applications is stored in the roots and that part is moved out of the medium-sized roots, the data do not indicate what fraction of this nitrogen taken in was moved into the very large roots, the trunk, or the scaffold limbs.

The decrease in the nitrogen in the medium-sized roots of all trees between April 15 and May 15 indicates a movement of nitrogen reserves from the roots. The nitrogen removed was in all probability translocated to such growing tissues as the terminals and spurs.

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Growth of Fruit and Stomatal Behavior of Elberta Peaches as Affected by Weather Conditions

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DAILY measurements of Elberta peaches were made as a preliminary study to determine some of the factors affecting the growth of the fruit and the possible connection between growth and stomatal behavior. Recent work with apples (2) has shown a very close correlation between the daily interval of stomatal opening and the growth rate of the fruit. Hendrickson (3) has observed that the stomata of certain stone fruit trees grown under conditions of little or no available soil moisture had a smaller maximum opening than those on trees growing in soil containing an abundant supply of moisture.

Work was conducted in a 20-year-old peach orchard of the University of Maryland, principally with the Elberta variety. Fifteen representative peaches on each of 5 trees were tagged July 6 and measured at daily intervals thereafter. Horizontal circumferences were taken and the measurements were converted to a volume basis. Temperature and rainfall records were obtained from the weather observer at the University. The method used in studying stomatal movement was similar to that used by Furr and Magness (2) with apples. A small section was torn from the peach leaf in such a manner that portions of the lower epidermis were exposed along the margin. These were examined with a microscope and counts were made immediately of the number of stomata open and closed.

The daily measurements of the fruit are shown in Fig. 1. The time of day the records were made proved to be an important factor, especially early in the season when growth was slow. On July 6 the fruit had a volume of 23.3 cc. and on the following day 23.8 cc. On July 8, however, the fruit had diminished in size to 23.1 cc. On the latter date measurements were made at 1:30 p. m., 5 hours later than usual. As a result the peaches were smaller than they had been two days previously. Measurements made July 14 at 6:30 a. m. averaged 25.03 cc. At 3 p. m. on the same day the peaches averaged only 24.66 cc., a shrinkage of .37 cc. during a period when the average daily growth was only 0.3 cc. On three other dates, July 22, July 26, and Aug 1, measurements were made in the afternoon and on each of these dates the fruit was smaller than it had been the previous day. Peaches made practically all of their growth during the night when humidity was usually high and temperature low. Shrinkage during the day was not noted, however, during the period of rapid growth.

From July 6 to August 9 the fruit increased in size (volume) only 12 cc. During the latter part of the period rainfall was lack-

ing, less than an inch of rain falling in scattered showers between July 17 and August 9. Unfortunately soil moisture determination was not begun until later, but the soil to a depth of 3 feet appeared dry and dust-like. Peach leaves showed definite signs of wilting and grass and weeds were thoroughly dried out.

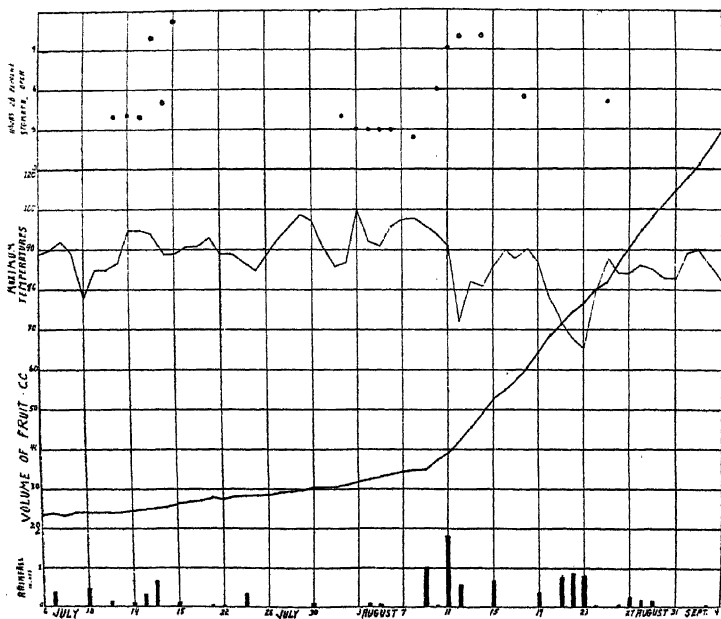


FIG. 1. Growth of fruit, daily maximum temperature, rainfall, and number of hours 20 per cent of stomata were open in peaches, College Park, Md., 1931.

In spite of this dry weather, the peaches suddenly started a steady growth on Aug. 2 of 0.7 cc. per day, at a time when the highest maximum temperatures of the summer prevailed. Previous to that date the average daily growth had been less than 0.3 cc. This acceleration in growth indicated termination of the period of depressed growth noted by various workers (1,4) for stone fruits, and the initiation of the period of rapid growth which occurs just prior to maturity.

In the afternoon of August 9 a heavy shower occurred in which more than an inch of rain fell. This increased moisture supply was immediately evident in a growth response of the fruit. The following morning the fruit showed an increase in size of 2.5 cc. Two days later 1.8 inches of rain fell, wetting the soil to a depth of 2 feet. In the four days following the rain the peaches made more growth than they had the month previously.

Rainfall was abundant the remainder of the season and the fruit grew at approximately the same daily rate until picked. There appeared to be no significant correlation between daily temperature and growth. The peaches grew just as much when the maximum temperature of the previous day was above 90 degrees F. as when

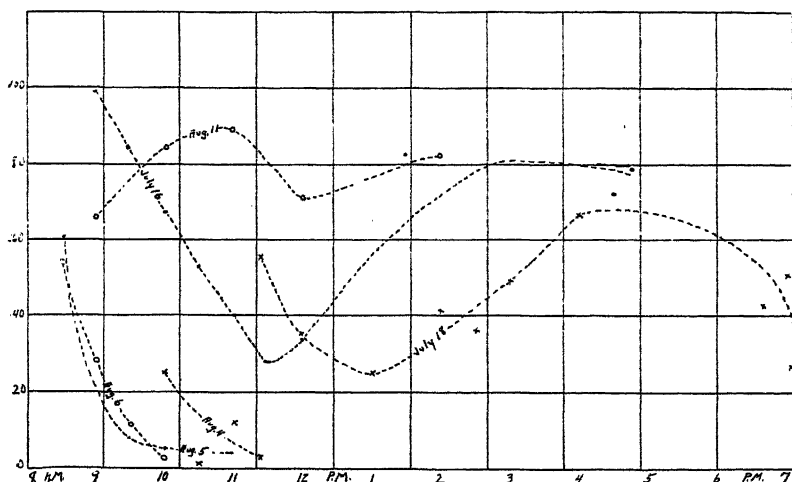


FIG. 2. Comparison of time of closure of stomata on various days.

the temperature did not rise above 80 degrees F., providing the variation in temperature occurred within a short time so the fruit was at comparable stages of maturity, and providing moisture was available.

Stomatal movement appeared to be more closely associated with daily temperature and humidity than fruit growth. Between August 3 and 8, during an extremely warm period with minimum humidity ranging between 20 and 30 per cent, the stomata closed very early as shown in Fig. 2. On August 5 and 6, practically all stomata were closed at 9 a. m. and on August 4 only 25 per cent were open at the same hour. As noted above soil moisture was lacking and peach leaves had wilted. August 11 was a cool, cloudy day with a minimum humidity of 75 per cent. A heavy shower occurred at 2:45 p. m. at which time 80 per cent of the stomata were open (Fig. 2), at least 65 per cent of them having been open all day. Stomatal movement on July 16 is also shown in Fig. 2. The morning was clear and hot, with a maximum temperature of 94 degrees F. at noon. A majority of the stomata as usual had closed before 11:30 a. m. At 1 p. m. the sky became overcast and the stomata reopened so that at 1:30 p. m., 60 per cent were active. In the succeeding two hours more than 0.6 inch of rain fell, and at 5 p. m. 70 per cent of the stomata were open. Stomatal movement on July 18 was very similar. Leaves examined at 7 p. m. just before

dark, had 40 per cent of the stomata open. Thus temperature and humidity, as well as soil moisture, are important in determining the daily interval of stomatal opening.

Elberta and Crawford stomata behaved very similarly until the fruit of the former had been picked. Then the Elberta stomata closed earlier, between 8 and 9 a. m., while the stomata of the Crawford trees on which the fruit remained continued to be active to the usual time of closure, just before noon.

To a certain extent growth of fruit was correlated with stomatal behavior. During hot, dry periods the stomata functioned for only a short time daily, and fruit growth was also inhibited, while during humid periods with an available supply of soil moisture stomata were active for the longest periods and fruit growth was most rapid. This relation may or may not be causal. Stomatal movement at least furnishes an excellent criterion of the moisture relations of the peach trees and indicates whether a sufficient moisture supply is available for maximum growth.

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The Relation of Soil Moisture and Spray Applications to Stomatal Behavior and Growth of Jonathan Apples¹

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DURING the season of 1931, investigations were conducted to determine the effect of (1) varying the amounts of irrigation water applied during the growing season from May 1 to September 1, and (2) varying the spray material applied, on the size and growth of Jonathan fruits and upon leaf stomata behavior. The trees were grown in an orchard with an average cover crop for the Wenatchee District—some alfalfa, and mostly weeds.

There were two series of test plots as follows: (1) Variation in amounts of water applied, from 21.7 acre inches to 53.5 acre inches with the same fertilizer and spray program; and (2) variation of spray program, including oils and other sprays but with the same fertilizer and irrigation.

The soil is made up of different deposits of fine and coarse sandy loam with occasional angular rock fragments 2 to 6 inches in diameter. This type of soil is several feet in depth. The wilting percentage of the soil was not determined definitely for these plots. Results from other tests and soil moisture analyses, however, show the wilting point to be approximately 4 per cent.

The total amounts of water, both rainfall and irrigation, applied to the four plots in the irrigation series during the growing season, from May 1 to September 1, varied as follows: Plot A, 34.5 acre inches; Plot B, 25.3 acre inches; Plot C, 21.7 acre inches; Plot D, 53.5 acre inches. The average soil moisture determinations of the upper three feet indicated that at no time did the per cent of water in any of the plots reach the wilting point, of 4 per cent, or exceed the field capacity.

The observations of the stomatal behavior with respect to the per cent that were open or closed at any time interval were essentially the same on all trees of each of the four plots.

The stomata were uniformly open, during the days examined, as late as 3 p. m. until August 3. On August 3, 4, and 7, there was a reduced percentage open during the hour from 9 to 10 in the morning, and a still lower per cent were open at three in the afternoon. On August 24, 25, and 28, there was a reduced number of stomata open in the morning and a further marked reduction in the number open in the afternoon on August 25. During these periods when the total number of stomata were more nearly closed, the average maximum temperatures (92 to 96 degrees F.) were the highest and the

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average minimum relative humidities (24 to 27 per cent) were the lowest for the season.

These observations are, therefore, in agreement with the deductions of Furr and Magness (1) who state that apple trees can function at near the maximum rate so long as the moisture content of the entire root zone is appreciably above the wilting percentage.

This indicates that with high temperature and low relative humidity an earlier closing of stomata may result, even though the soil moisture is above the wilting point, while no stomatal response differences were shown by variations in amounts of soil moisture between wilting point and field capacity. With a good alfalfa cover crop growing in the orchard the temperature tends to be lower and the relative humidity higher than where clean cultivation is practiced.

Apples were tagged and measured every three days on three trees on each plot, both with random and controlled² leaf area samples. The data shown in Fig. 1 are from random samples; that shown in Fig. 2 are from controlled leaf area samples. The indicating growth line of fruit shows but little variation in any of the tests. At no time during the season was there a measurable checking of the fruit growth even with high temperature and low humidity.

Volumetric measurements showed that the fruit gradually and consistently increased in size throughout the season on all plots in a comparable manner. These data are in agreement with the findings of Veihmeyer and Hendrickson (2). They reported, "Observations extending over a number of years in deciduous fruit orchards of California indicate that the soil moisture supply may fluctuate between wide limits without measurably affecting the growth of tree or yield and quality of the fruit."

Stomata studies and growth measurements of fruit were also made on plots receiving applications of different spray materials but all with the same irrigation (34.7 acre-inches of water) and fertilizer treatment. The sprays were all applied with a gun at 425 lbs. pressure and every side of the fruit and leaves were wet. The spray program for the four plots was as follows: Plot E, lead arsenate, 2 lbs. to 100 gallons, in calyx and five cover sprays; Plot F, lead arsenate, 2 lbs. to 100 gallons plus 1 lb. spreader to 100 gallons of the mixture, in calyx and five cover sprays; Plot G,

²The controlled leaf area samples were from ringed branches thinned to 15 leaves per apple.

EXPLANATION FOR FIG. 1.

FIG. 1. Stomata and Fruit Growth Behavior on the Irrigation Series of Plots.

- (1) Growth line of fruit in volumetric cc. (2) Maximum temperature in degrees F. (3) Per cent stomata open from 9 to 10 a. m. (4) Per cent stomata open from 2 to 3 p. m. (5) Relative minimum humidity in per cent. (6) Irrigation water applied in acre-inches. (7) Average per cent of soil moisture in first 3 feet of soil 10 feet from tree. (8) Rainfall in acre-inches. (Max. temp. and min. humidity the same for all plots as shown in Plot A.)

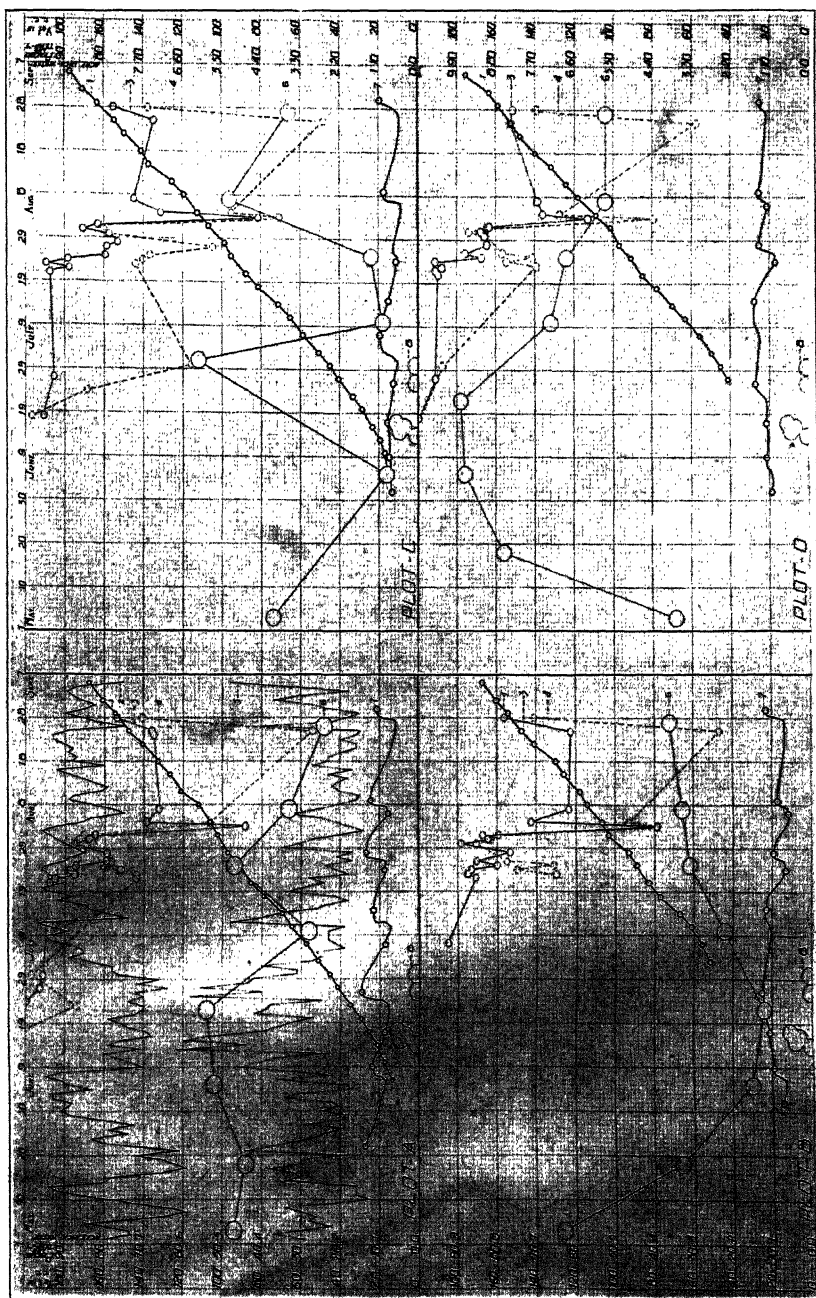
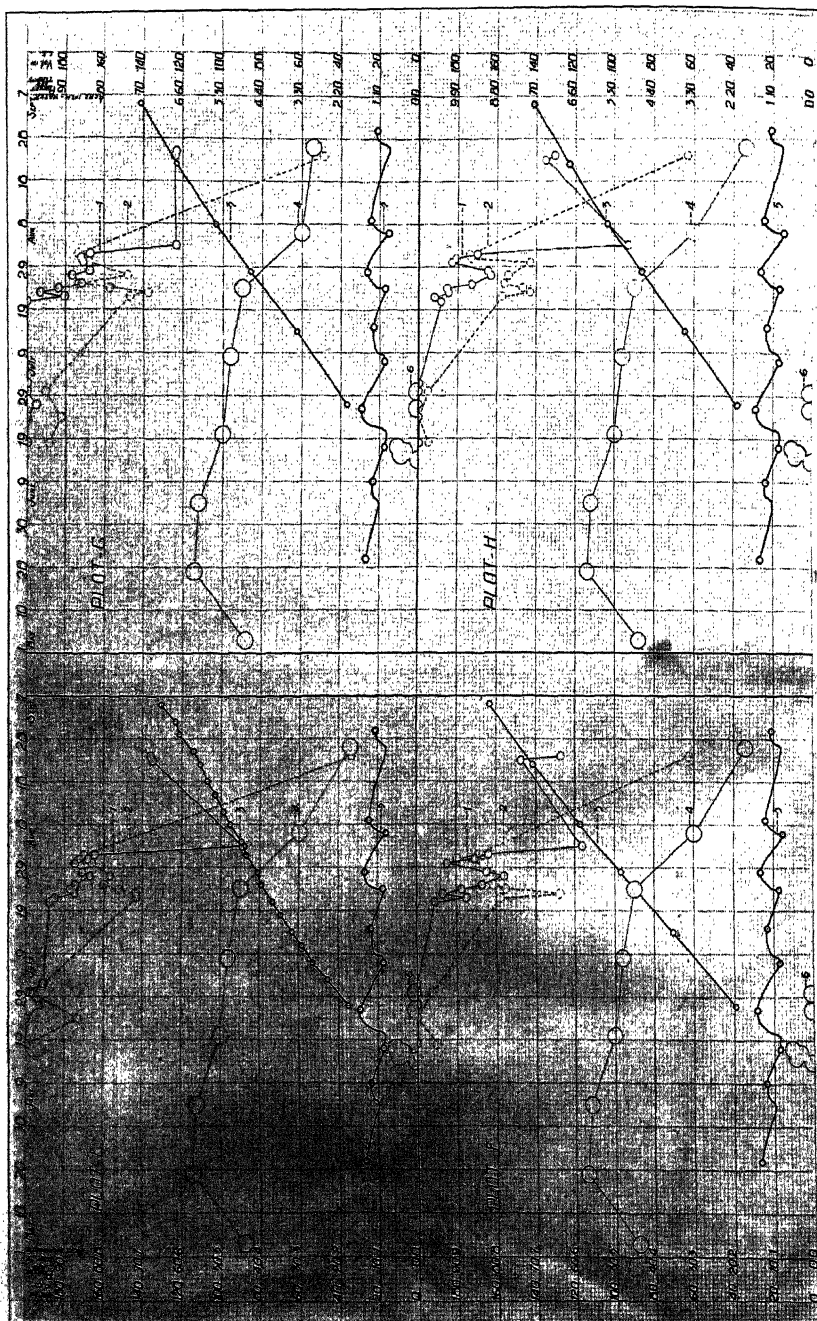


FIG. 1.



rotenone, 8 ounces to 100 gallons water (rotenone first dissolved in 1 gallon acetone), in calyx and five cover sprays; Plot H, lead arsenate, 2 lbs. to 100 gallons plus 1 gallon oil emulsion of light, medium type oil, 65-75 viscosity, in first five cover sprays and oil nicotine sulfate in the 6th cover. There were no significant consistent differences in the stomatal response of the leaves of the trees on the plots receiving varied spray applications. With adequate soil moisture supply, none of the types of spray materials used exerted any measurable influence upon the opening and closing of the stomata.

TABLE I—AVERAGE SIZE AND COLOR OF FRUIT FROM IRRIGATION AND SPRAY PLOTS OF JONATHANS, 1931

Plot	Average Number Apples per Tree	Average Weight of Fruit (Lbs.)	Average Per cent Color of Fruit	Average Circ. of Tree (cm.)
A	2,753	.328	71.5	85.0
B	2,381	.316	87.2	91.3
C	2,539	.351	84.5	88.0
D	2,715	.351	79.8	89.3
E	2,753	.328	73	85.0
F	3,203	.369	73	93.0
G	2,969	.323	75	89.0
H	2,599	.362	71	92.6

On branches with controlled leaf area, there were no differences in rate and character of size increase of fruits on plots F, G, and H, as shown in Fig. 2. The growth of the fruit measured in Plot E was less throughout the season than the growth of the other plots. The average size of the fruit on plot E, or straight lead arsenate sprayed plot, at harvest time, was 129 apples per 42 lbs. box, compared to 117 apples per box from plot H, with light, medium oil spray in six covers. A better control of some of the leaf-injuring insects (especially the woolly aphis) was noted on the light, medium oil sprayed plot and thus the leaves functioned more efficiently photosynthetically. This is in agreement with results reported by Spuler, Overley and Green (3), "Fruit on trees receiving a light oil (viscosity 50-55), however, was even larger than fruit sprayed with lead arsenate." In other tests, however, where heavy oils (110-120 viscosity) were used in only three applications on heavily loaded Rome trees, the fruit averaged almost two commercial box sizes smaller than that from lead arsenate sprayed plots, even though red spider and other leaf-injurious insects were controlled.

EXPLANATION FOR FIG. 2.

FIG. 2. Stomata and Fruit Growth Behavior in the Spray Series of Plots. (1) Per cent stomata open 9 to 10 a. m. (2) Per cent stomata open 2 to 3 p. m. (3) Growth line of fruit in volumetric cc. (4) Irrigation water applied in acre-inches. (5) Average per cent of soil moisture in first 3 feet of soil 10 feet from tree. (6) Rainfall in acre-inches. (Max. Temp. and Min. humidity the same for all plots as shown in Fig. 1, Plot A.)

Apparently the heavy oils may have injured the leaves to the extent that their photosynthetic capacity was lowered.

The apples grown with the controlled leaf area, of 15 leaves per fruit on ringed branches, were smaller than the random samples measured or the average size of fruit from the trees which had a larger leaf area per fruit. This accounts for the larger fruit shown by the growth line in plot A compared with the growth line for plot E with the same irrigation and spray schedule.

A comparison of the average size and color of all fruits harvested from the various plots of three trees each is given in Table I.

The average size and color of the harvested fruit from the various plots showed considerable variation, which was probably due to a difference in load of fruit per tree or the leaf area per apple, rather than to the spray or irrigation program.

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Relation of Moisture Supply to Stomatal Behavior of the Apple

By J. S. FURR and E. S. DEGMAN, *U. S. Department of Agriculture, Washington, D. C.*

THE influence of moisture upon fruit growth and stomatal behavior of apples in the exceptionally dry season of 1930 was shown in a previous paper (1). This paper reports the results of similar studies at Hancock, Md. for the more nearly normal season of 1931. For the period May-Sept. inclusive, the rainfall in 1931 totaled 18.2 inches. A ten-year average for the same period is 17 inches.

The studies reported here were not conducted on the plots used in 1930. In the spring of 1931, trees on plots irrigated in 1930 were much more vigorous than those on non-irrigated plots. To obtain comparable trees it was necessary, therefore, to select trees which had had no previous treatment. Furthermore, it was desirable to locate the plots on soil comparatively free from large rocks, so that soil samples could be taken with a soil auger.

Four plots were laid out in a 10-year-old Grimes Golden and Delicious planting. The trees were 22 feet apart. The soil, a shaly loam, had been in clover sod for several years, but in the spring of 1931 was plowed and cultivated. Four Grimes Golden and six Delicious trees received irrigation; five Grimes Golden and four Delicious trees, no irrigation. The Delicious plot was irrigated by the furrow method, the Grimes Golden plot by over-head sprinklers.

The growth rate of fruit was determined by measuring with a steel tape the circumference (perpendicular to the axis) of 15 fruits on each tree twice a week. The volume of each fruit at each date was obtained from a conversion table, assuming the fruit to be a sphere and the average volume for each date was calculated.

The method used for determining stomatal behavior was the same as that described in a previous paper (2), except that, instead of estimating the width of aperture of each stoma observed, 50 stomata were counted per leaf observed and the number of stomata open was recorded with a Veeder counter. Usually four leaves were taken from each tree at intervals of from 45 minutes to one hour. The percentage of stomata open on a plot at a given time thus represents the average condition of 400 to 600 stomata. The variability in percentage of stomata open between leaves of the same tree was found to be unusually high for these trees. It is believed that this was due in part to severe hail injury, which occurred in these plots since much less variability was found for trees outside of the hail area.

Stomatal data and soil samples were taken from each of the Grimes Golden trees. It was assumed that soil moisture conditions

would be approximately the same on the Delicious plots which were adjacent.

A separate soil sample was taken at 3, 6, and 12 feet from the trunk of each tree. The surface two feet were taken, each foot separately. Each sample was a composite of soil from several bore holes. So little variation in moisture distribution was found that the average of all samples from a plot have been used in this paper.

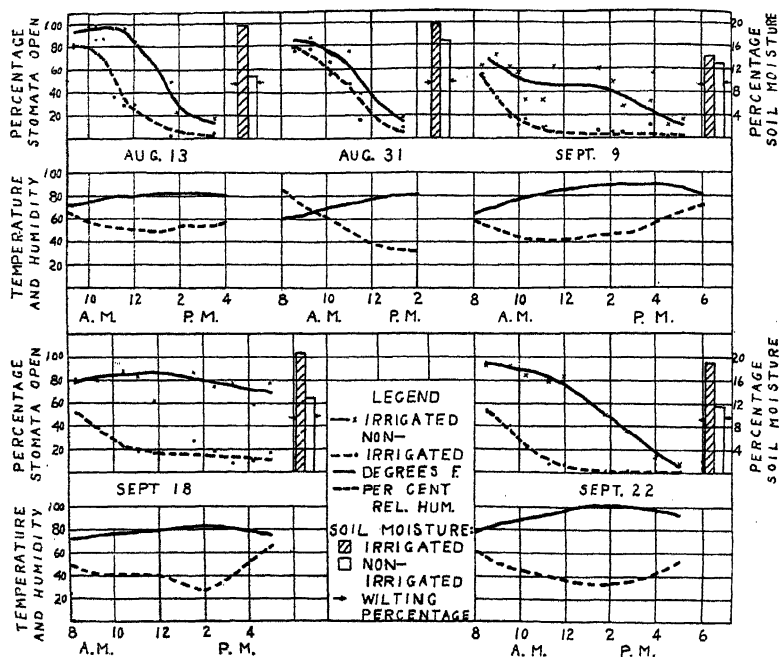


FIG. 1. Soil moisture, fruit growth, irrigation, and rainfall on irrigated and non-irrigated plots. The heavy horizontal line at 9.5 per cent soil moisture represents the wilting percentage. The broken portions of the soil moisture curves are assumed, the solid portions are the actual slope.

A layer of shale 2 to 3 feet below the surface, prevented sampling to a greater depth. The plot average was calculated from all samples taken on the plot. The wilting percentage of the soil was determined by growing sunflowers in sealed cans.

Tagged fruits were measured twice a week beginning July 21. A severe hail storm on July 27 injured the foliage and fruits, necessitating some substitutions for tagged fruits.

DISCUSSION OF RESULTS

The curves for fruit volume (Fig. 1) show that the fruits on the non-irrigated plots were slightly larger than those on the irrigated plots at the start of the measurements.

On Aug. 1, approximately 3 acre-inches of water were applied to the Delicious plot; the Grimes Golden trees received about half of this quantity on Aug. 1 and the remaining half on Aug. 7. There was an immediate increase in the growth rate of the fruit on the irrigated plots.

The moisture content of the soil in both plots decreased until Aug. 19, when about 2 inches of rain fell during a 4-day period. Before this rain, the soil moisture of the non-irrigated plot was approximately at the wilting percentage in the surface two feet, while that of the irrigated plot was about 6 per cent above the wilting percentage. After this rain, the rate of growth of the fruit on the non-irrigated plot increased until it paralleled that of the irrigated fruit, and remained about parallel until Sept. 10, when the fruit of the non-irrigated plot tended to slow up in growth rate, though this change was not marked. At this time, the soil of the non-irrigated plot was about 4 per cent above the wilting point. During the remainder of the season, the soil moisture content of the non-irrigated plot remained 3 to 4 per cent above the wilting percentage.

Fig. 2 shows graphically the influence of soil moisture, temperature, and relative humidity upon stomatal behavior for several typical days during the season.

Aug. 13 was partially cloudy, with high relative humidity and relatively low temperature; i.e., insolation and saturation-deficit were relatively low. On Sept. 22, the temperature was higher and the relative humidity was lower than on Aug. 13, but the soil moisture conditions were about the same for the two dates. The percentage of stomata open on the irrigated plot on Aug. 13 was 20 to 50 per cent higher than that of the non-irrigated plot—a difference due to the difference in soil moisture. The percentage of stomata open on the non-irrigated plot on Aug. 13 was, however, strikingly higher—about 50 per cent at 10 a. m.—than that of the same plot on Sept. 22, though the soil moisture was about 3 per cent above the wilting percentage in both cases. This difference must, therefore, be due to differences of temperature and humidity. These curves show that both soil moisture content and weather conditions may act at the same time to influence stomatal behavior, and that, even though the soil moisture content be near the wilting percentage, under conditions unfavorable for high transpiration the tree may maintain a fairly high percentage of stomata open.

On Aug. 31, with over 16 per cent soil moisture on both irrigated and non-irrigated plots, the difference in percentage of stomata open was slight, 10 to 15 per cent. However, with bright sun and rapidly decreasing relative humidity, there was likewise a rapid decrease in the percentage of stomata open on both plots.

The data for Sept. 9 and Sept. 18 show that the percentage of stomata open on the irrigated plot increased by 30 to 60 per cent when the soil moisture was increased from 5 per cent to 11 per cent above the wilting percentage. During this period, there was little change in soil moisture on the non-irrigated plot, but the per-

centage of stomata open increased about 10 per cent. This indicates that conditions were more favorable for stomata to remain open on Sept. 18 than on Sept. 9; but the change in the percentage of stomata open was so much greater on the irrigated than on the

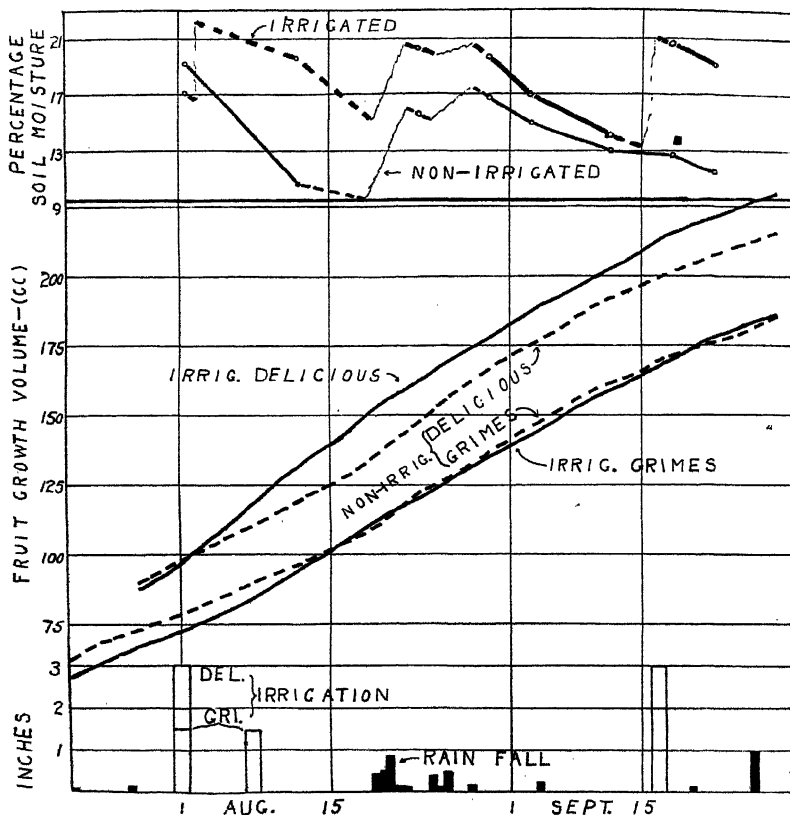


FIG. 2. Percentage of stomata open, temperature, relative humidity, and soil moisture on irrigated and non-irrigated Grimes Golden trees on typical days.

non-irrigated plot that it seems safe to conclude that on this soil the rate of supply of moisture to the tree was a limiting factor in stomatal opening while the soil moisture was still 5 per cent above the wilting percentage.

The influence of high temperature and low humidity on stomatal behavior is illustrated by the curves for percentage of stomata open on Sept. 22 on both the irrigated and non-irrigated plots. Though the soil moisture content was high on the former and low on the latter, the percentage of stomata open steadily decreased until closure was practically complete—at noon on the non-irrigated and at 5 p. m. on the irrigated plot.

The influence of soil moisture upon fruit growth was less striking than upon stomatal behavior. The crops carried by these trees were rather light in relation to leaf area per fruit, and the fruits attained large size on both plots. This suggests that, even though leaf function may have been reduced on the dry plots, sufficient carbohydrates were formed to provide for almost normal growth of the fruits.

Hendrickson and Veihmeyer (3) concluded, as a result of their work on peaches, that yield and growth of trees are not measurably influenced by soil moisture content until it is reduced to about the permanent wilting percentage. They state: "The data in this paper lead to the conclusion that no differences in the yield, growth of trees, time and relative amount of blossoming, or quality of fruit were brought about so long as the soil-moisture content was above the permanent wilting percentage."

The data presented here on the behavior of apples under conditions of varying moisture supply indicate that the relative amount of available soil moisture had a measurable, though slight, influence on fruit growth and a marked influence on stomatal behavior while the soil moisture was several per cent above the wilting percentage.

It is probable that, had the trees carried a heavy crop, the difference in fruit growth would have been more pronounced. We believe stomatal behavior to be an index to leaf function, though perhaps such a sensitive index, that environmental conditions which noticeably influence stomatal behavior may not show an immediate measurable influence upon growth rate of fruit.

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Light Intensity as a Factor in the Development of Apple Color and Size¹

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THE natural shading of apples by foliage on the trees has been recognized for many years as an important factor contributing to poor development of red color. Paradoxically, insufficient amount of foliage for a given fruit has loomed as a factor in the poor development of red color of apples, according to recent work of Fletcher (2), Haller (3), and Magness (4). Associated with these leaf area relations, accumulation of sugars in the fruit is apparently closely related to color development. Since leaf function apparently is associated with red color, it is probable that natural shading of fruits by foliage exerts an influence by the shading effect on the leaves adjacent to the fruit, as well as on the fruit itself. The experiments herein described consider only the effects when the fruits alone are shaded.

Quality of light has received most of the attention in recent work on red color. The intensity or amount of light, although of great practical importance, has been given scant attention. Overholser (6) in 1917 used dark cloth bags on apples to exclude light and no red color resulted except for light streaking on Williams. He reports that bagging with sacks of white material (textile not specified) color development was practically normal.

MATERIALS AND METHODS

Young developing apples on 10 to 15-year-old trees of several varieties were covered with cloth bags to reduce in varying degrees the amount of light which reached such fruits. Bags about 8 inches square were made of cheese cloth of double thickness, unbleached muslin of single thickness, and muslin of double thickness. When the bag was placed on the apple, the opening was sewed up, and the weight of the bag was supported by a string attached to the twig. No leaves were enclosed in the bags. Fruits were selected on the outer portion of the tree well exposed to light before bagging, and uniformity of size was sought. About 20 fruits on each variety were placed under each type of bag, and a similar number of check fruits were selected adjacent to the bagged fruits. The time of bagging for each variety in 1930 was, Wealthy on July 1, Summer Rambo and McIntosh on July 6, King David on July 15, and Jonathan on July 20. In 1931, Wealthy, McIntosh and Oldenburg were covered June 18, Williams and Summer Rambo on June

¹This study is a phase of a joint project on factors affecting red color of apples, carried on by the Department of Horticulture, University of Maryland, and the Office of Horticultural Crops and Diseases, U. S. Department of Agriculture.

28. York Imperial and Northwestern Greening on July 6, and Jonathan on July 10. The fruits had little or no color at the time of bagging.

TABLE I—EFFECT OF CLOTH BAGGING ON THE SIZE OF APPLES

Variety	1930				1931			
	Circumference of Fruit (Cms.)				Circumference of Fruit (Cms.)			
	Check	Cheese Cloth	Single Muslin	Double Muslin	Check	Cheese Cloth	Single Muslin	Double Muslin
Jonathan.....	20.31	19.84	19.57	19.41	23.14	21.77	21.88	21.18
Wealthy.....	21.35	22.51	21.99	18.41	23.78	23.38	23.94	22.78
McIntosh.....	21.55	21.01	21.72	18.70	24.40	24.16	24.42	22.57
S. Rambo.....	24.61	23.98	22.05	21.81	25.87	25.23	24.64	23.27
King David.....	18.39	18.48	18.00	—	—	—	—	—
York.....	—	—	—	—	24.29	23.48	22.85	22.00
Oldenburg.....	—	—	—	—	22.08	22.70	22.20	22.60
Williams E. R....	—	—	—	—	20.88	20.31	20.42	19.90
N. W. Greening..	—	—	—	—	23.78	22.92	23.28	22.21
Average all varieties.....	21.24	21.16	20.66	19.57	23.40	22.99	22.95	22.06

The relative intensity of light which passes through the various bags was determined by means of a Weston illuminer in the photometry laboratories of the Bureau of Standards with the kind assistance of Drs. J. F. Meyer and R. P. Teele. The relative transmissions considering the unscreened light as 100 per cent, were as follows:

Cheese cloth (double thickness).....80.8 per cent
 Muslin (single thickness).....61.4 per cent
 Muslin (double thickness).....39.2 per cent

Since recent work of Magness (5) and Fletcher (2) has indicated that the ultra violet region is the effective part of the spectrum in apple color development, (although Pearce and Streeter (7) place it just above the ultra violet at 3600 to 4500 Å.), it is apparent that the amount of ultra violet light transmitted by the above fabrics would be important in this study.

According to Dr. W. W. Coblentz (conversation December 1931) of the Bureau of Standards, who has worked on transmission of ultra violet rays through various fabrics (1), the cheese cloth would have practically no selective action on the relative amount of ultra violet light transmitted. Muslin would have some selective action, probably reducing the transmission of ultra violet light to the extent of ten per cent.

RESULTS

Marked effects from reduced light intensity on the development of red color were secured in both seasons and some reduction in size of fruit also was noted.

As shown in Table I and Plate I, apples under double muslin developed very little color. Some color was produced under single

muslin and still more under double cheese cloth, but even the shading by cheese cloth reduced color by an average of 40 per cent in 1930 and 60 per cent in 1931 as compared with unshaded fruit. It is apparent that relatively slight shading of the fruit has a marked effect on color development. In both years, the results were similar.

TABLE II—EFFECT OF CLOTH BAGGING ON THE COLOR OF APPLES

Variety	1930				1931			
	Per cent Red Color per Apple				Per cent Red Color per Apple			
	Check	Cheese Cloth	Single Muslin	Double Muslin	Check	Cheese Cloth	Single Muslin	Double Muslin
Jonathan.....	83.65 (18)	52.14 (13)	20.80 (18)	0.00 (15)	90.62 (20)	48.18 (20)	7.31 (20)	0.00 (20)
Wealthy.....	68.84 (19)	50.35 (18)	26.04 (19)	3.04 (18)	80.50 (10)	24.00 (10)	0.00 (10)	0.00 (10)
McIntosh.....	54.75 (20)	24.60 (20)	6.60 (20)	0.0 (20)	44.15 (15)	13.88 (10)	5.2 (10)	0.00 (10)
S. Rambo.....	30.00 (15)	0.01 (16)	0.0 (15)	0.0 (15)	0.0 (18)	0.0 (18)	0.0 (18)	0.0 (19)
King David.....	82.09 (21)	56.80 (21)	28.13 (21)	—	—	—	—	—
York.....	—	—	—	—	65.95 (21)	38.50 (21)	3.1 (21)	0.0 (22)
Oldenburg.....	—	—	—	—	45.00 (16)	15.00 (10)	1.00 (9)	0.00 (8)
Williams.....	—	—	—	—	70.85 (30)	21.60 (22)	5.10 (22)	1.55 (21)
N. W. Greening..	—	—	—	—	0.00 (17)	0.00 (17)	0.00 (17)	0.00 (17)
Average of all varieties.....	63.86	36.78	16.31	0.60	49.63	20.14	2.71	0.19

Note: Figures in parenthesis represent the number of apples bagged in each case.

Usually more color developed under the bags in 1930 than in 1931, which might be associated with low soil moisture in the 1930 season.

Varieties differed in response to the shade imposed. Early varieties as Wealthy, McIntosh, Williams, and Summer Rambo, as a whole, were affected more adversely than later varieties. Some varieties were more sensitive to slight shading by cheese cloth than others. Summer Rambo, which develops poor color normally, was very intolerant of shade.

Differences in size were apparent on some varieties when the fruit was harvested in 1930, so that circumference measurements were made, as shown in Table II, presented as averages per fruit. Also in a rough way, by selection of fruits for photographing, the size differences in Table I are portrayed in Plate I. The averages in Table I

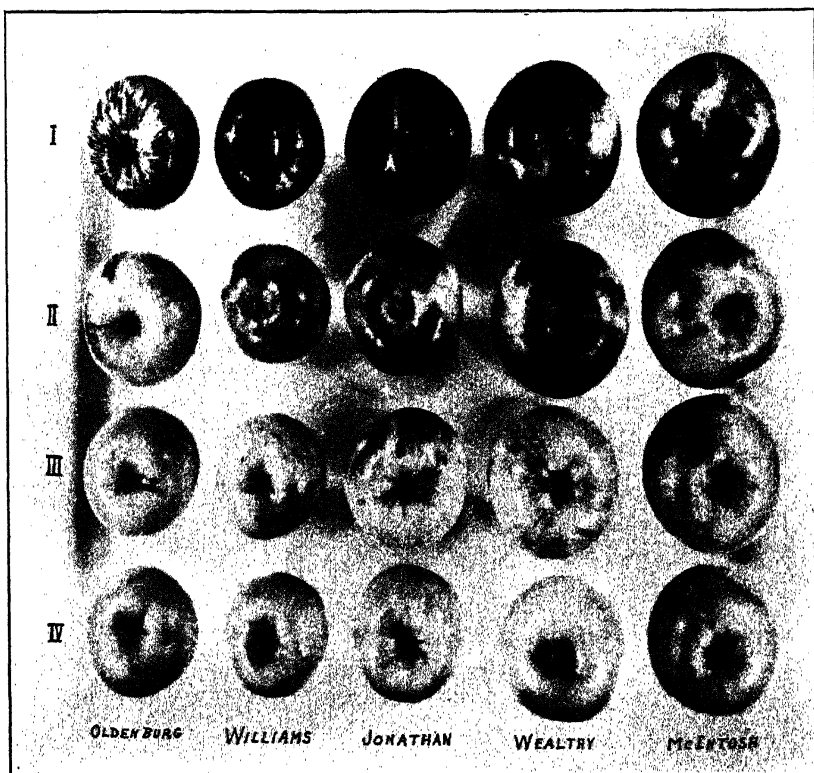


PLATE I. Effect of varying light intensity on red color development of apples.

Series I. After development under normal light conditions.

Series II. After development under double cheese-cloth bags, transmitting 80.8 per cent of normal light.

Series III. After development under single muslin bags, transmitting 61.4 per cent of normal light.

Series IV. After development under double muslin bags, transmitting 39.2 per cent of normal light.

show a definite and consistent decrease in size of fruit resulting from the shading with double muslin, the amount of decrease in some cases being as great as 15 per cent. There also is a tendency with some varieties to be affected in size by the lesser shading with cheese cloth and single muslin.

The effect of shading on size of fruit in these experiments is possibly due to lessened photosynthetic activity of the chlorophyll in the apple itself since the subtending leaves were not shaded. Investigations have shown lessened photosynthesis as well as lessened chlorophyll content in plants under reduced light intensity. Little or no visible evidences of lessened chlorophyll were observed in the case of the bagged fruits.

There is a possibility that temperature differences which probably occurred between bagged fruits and unbagged fruits had some effect on size as well as color. No temperature measurements were made.

CONCLUSIONS

Development of red color of apples may be decreased to a marked degree by relatively slight shading of the fruit. The amount of light as a factor in red color development of apples thus assumes greater importance and emphasizes the need of pruning of trees and thinning of fruits as practical means of admitting more light to fruits. When old bearing trees are invigorated by nitrogen fertilization with the consequence of many inside branches brought into bearing and greater foliage on the tree, the lessened amount of light to such inside fruits, apparently is a limiting factor on color and size.

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Little-Leaf or Rosette in Fruit Trees

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THIS disease seems almost certainly to be caused by a condition in the soil rather than by a parasite. The symptom that seems to identify it with most certainty is the opening in spring of tufts or rosettes of leaves that are very small, rarely as much as 5 per cent of the normal area for the variety. In Fig. 1 are shown the spring little-leaf tufts on a Japanese plum tree and a normal healthy shoot such as may grow later in the season from below a little-leaf tuft. On trees more badly affected such shoots may start with healthy leaves, but as the season advances the leaves may be continuously smaller with yellow mottling. Thus badly affected trees look worst in early spring when they have only the abnormally small, usually mottled, leaves; best in early summer when shoots may bear green, normal leaves; and bad again when the later leaves on these shoots are small, distorted, and mottled with yellow. In some orchards the first symptoms may be this mottling in late summer, the little-leaf effect appearing the next spring.

In very many orchards the trees make normal or exceptionally strong growth during the first few years, showing mottling in late summer of the third or fourth year. It is probably the same disease as that described as Apple Rosette (2) in Washington and elsewhere (3). However, since all the stone fruits, the walnuts, citrus fruits, grapes, and many other kinds of plants, are susceptible to it, and since there is another disease of the peach known as Rosette, the term Little-leaf, long used in California (1, 4) seems better. Trees growing in deep, well drained, sandy or gravelly soils having very little clay are most likely to be affected, though it may affect trees growing in soils having enough clay to make excellent sandy or gravelly loams. In some soils, trees that receive less water at each irrigation than the others in the orchard show less of the disease. Yet it is bad in some orchards that are not irrigated.

In Washington, with apples, continuous growing of alfalfa in the orchard nearly always corrects the trouble, though if the alfalfa is ploughed up and not replanted it appears again within about three years. In California there is less experience with alfalfa, but a fair number of peach, apricot, and plum orchards have been observed in which, after about three years in a good stand of alfalfa, affected trees gradually became healthy, whether the alfalfa is left on the ground or removed for hay. However, in a few of the orchards observed the trouble developed so rapidly that sowing alfalfa after the symptoms became striking did not correct the trees, or even prevent their dying. In California, soils in which trees show little-leaf have a reaction between pH 6.8 and pH 8. When the reaction is above pH 8, the trees seem less apt to show little-leaf symptoms.

In one section where the soil is rather acid, pH 5 to pH 6, apple trees show symptoms that seem identical with little-leaf in other parts of California and in Washington; but during the past few years all trees have improved, checks as well as treated trees, so that it has not been possible to learn whether or not these trees will respond to the same treatments that correct little-leaf trees in other sections.

EXPERIMENTAL TREATMENTS

In January 1928 extensive treatments were begun in several sections of California where little-leaf was causing very great losses. Among the substances tried was ferrous sulphate, used in amounts of 3 to 30 pounds to the tree. In the spring after the treatment, little-leaf symptoms appeared as on untreated trees; but on trees had enough for early summer leaves on the shoots to be mottled with yellow, the leaves formed after the middle of May or the first of June, $2\frac{1}{2}$ to 3 months after growth started, were normal if 20 to 30 pounds of ferrous sulphate had been used. When this effect was observed, other plats in these sections and plats in other sections were treated, some in June, some on July 2, 1928, trees being used for treatment and checks that, in addition to the spring little-leaf, showed rather small, distorted, mottled leaves along the shoots. Four to five weeks after this ferrous sulphate was leached into the soil, trees that were still growing showed green, normal leaves at the apex of the shoots, provided enough ferrous sulphate had been used.

A scientific explanation of these results that would enable one to predict the response of trees in different soil types was not found, and so it was thought best to make trials extensive enough to determine whether in all soils trees showing these symptoms would be corrected by this treatment. Accordingly plats of trees showing little-leaf were located in 10 counties, 26 localities. More than 2,000 trees were treated and 56 tons of ferrous sulphate were used. In all cases trees equally had were left as checks to show whether or not there was any tendency for trees in any of the orchards to recover without being treated. Apple, pear, peach, plum, cherry, and walnut trees and grape vines were treated. In seven counties of the San Joaquin valley, along the 250 miles from Lodi to south of Bakersfield, ferrous sulphate made at a local plant from scrap iron containing a considerable amount of zinc always corrected the trouble if enough was used; but it sometimes required as much as 125 pounds to the tree. In sandy soils containing very little clay and very little carbonates, 15 to 20 pounds would make a tree nearly normal, though 30 to 40 pounds would usually make it still better, especially if it was so bad that nearly all the shoots in the top were dead. The more clay and the more carbonate there was in a soil, the more ferrous sulphate it required to correct a tree. Ferrous sulphate forced deep into the soil through a pipe attached to a spray machine was not nearly as effective in correcting little-leaf as the same amount spread on the surface of the soil and leached in.

At first the material was spread over all the soil area occupied by a tree, but later it was found that, for peach and plum trees at least, spreading it in a radius of 3 to 4 feet from the trunk gave as good results, or better.

A treatment in winter does not prevent the little-leaf effect in the spring following; but if the shoots bear abnormal, mottled leaves, green healthy leaves will appear by June after the treatment. If the little-leaf is not bad enough for the summer shoots to bear abnormal leaves, the benefit is not seen until the second spring after the treatment. A treatment during the growing season does not prevent the little-leaf effect in the following spring unless many of the shoots on the tree continue growing more than a month after the treatment.

The effect of a treatment is not permanent. Often during the third summer following a treatment the symptoms reappear, though usually much less material is required to correct the trees a second time. Until the third summer the effectiveness of the treatment is very striking. Trees so badly injured that they bore no healthy leaves and no fruit except culls have been made to yield as much as 15 tons of marketable fruit to the acre.

Ferrous sulphate is highly acid and most of the soils in which these improvements resulted are at least slightly alkaline. It was thought possible that the benefits of the treatments might be due to a reduction in alkalinity or in the amount of sodium obtained by the tree. In fact, when the experiments began, trees were treated with as much as 20 pounds of sulphur each and others with as much as 100 pounds of calcium sulphate. Later, trees were treated with sulphuric acid, hydrochloric acid, and alum, each treatment supplying as much acid as would be supplied by the amount of ferrous sulphate necessary to correct the trees, or more. The soil was eventually made most acid by the sulphur treatments. None of these treatments caused any improvement in the trees except that at one place where there was a considerable amount of carbonate, sulphur applied with the ferrous sulphate seemed to reduce the amount of ferrous sulphate necessary to correct the trees.

It was thought possible that the ferrous sulphate might correct the trouble by precipitating injurious sulphides and that for such an action copper sulphate should be even more effective. Copper sulphate, 20 to 50 pounds, was applied to trees that would be corrected by 30 pounds of ferrous sulphate. There was no appearance of benefit, although even the largest amounts did not seem to cause injury. Also in controlled experiments carried on for two seasons, regular applications of comparatively large amounts of saturated hydrogen sulphide water failed to produce injury to young peach trees.

The ferrous sulphate was analyzed and was found to contain nearly 1 per cent of zinc. It seemed possible that this might be the source of benefit. Accordingly, 40 pounds of chemically pure ferrous sulphate were applied to one tree and 35 pounds to another,



PLATE 1. Little-leaf tufts on *Prunus salicina*, and a healthy shoot such as may grow from just below Little-leaf branchlets.

either of which would certainly have been corrected by these amounts of the impure ferrous sulphate containing zinc; and $6\frac{3}{4}$ pounds of zinc sulphate were applied to each of three such trees in the autumn of 1930. The chemically pure ferrous sulphate has not corrected the trees and there is not conclusive evidence of any benefit at all. One of the trees treated with zinc sulphate died, apparently in part from the effect of nematodes. The other two, although they were very severely affected with little-leaf when treated, are now completely free of the trouble and in a vigorous condition.

By accident, in 1930 a considerable amount of ferrous sulphate was used that came from Belgium and contained much less zinc than that used before. It proved to be very much less effective, 40 to 70 pounds failing to correct trees that would be corrected by 30 to 40 pounds of that containing more zinc. These facts make it seem probable that nearly all if not all the beneficial effect of the impure ferrous sulphate was due to the zinc sulphate contained. Consequently, experiments with zinc sulphate as extensive as those with ferrous sulphate are being started. Apparently the plant requires a small amount of zinc in a culture medium. However, a mixture supplying nearly as much zinc as the ferrous sulphate supplied failed to benefit the trees. Possibly the ferrous sulphate may reduce the amount of zinc sulphate necessary to correct a tree.

It seems most probable that the zinc sulphate acts by breaking up or precipitating some injurious and unknown chemical either in the soil or after absorption by the tree, or else by inhibiting the growth of micro-organisms capable of producing toxic compounds. A preliminary suggestion has been obtained that the successful treatments have modified the character of the soil flora. Trees are being injected with zinc sulphate, however, and are to be sprayed with a zinc Bordeaux when in foliage, to see if the little-leaf may be a mere deficiency of zinc. Injections with ferrous sulphate or other iron compounds have not been effective, but they would probably not contain enough zinc.

The impure ferrous sulphate, of course, contained small quantities of many other substances that could possibly have caused the benefit, but a mixture containing cobalt, bromine, iodine, chromium, strontium, barium, tin, nickel, boron, and lead, in quantities larger than would probably be contained in the ferrous sulphate neither corrected little-leaf in trees already affected nor prevented healthy trees from becoming affected. We have seen that copper would not correct the trouble, though there is another disease of trees that is corrected by copper. Three pounds to the tree of manganese sulphate caused no improvement. However, to avoid any uncertainty as to whether or not the improvement caused by the technical grade of zinc sulphate may be due to some impurity, a number of trees are being treated with chemically pure zinc sulphate.

RELATION OF LITTLE-LEAF TO FERTILIZERS

At first it was thought that the trouble might be due to a deficiency of some of the better known essential elements. It was soon learned, however, that adding large quantities of nitrogen as ammonium sulphate, calcium nitrate, dried blood, or manure, would not cause improvement in affected trees or prevent healthy trees from becoming affected. In fact, abundant nitrogen in the soil usually increases the severity of little-leaf.

Nearly all the soils in which the studies were made were rich enough in phosphorus to grow excellent alfalfa without application of that element, and 15 pounds of superphosphate to the tree did not cause improvement in affected trees or prevent trees that had been corrected with ferrous sulphate from becoming affected again.

The symptoms of little-leaf are not at all like those of potassium deficiency, but bark on the roots of trees badly injured by little-leaf may contain no more than 10 per cent of the normal potassium content. It seems probable that this is due to an injury to the bark that permits leaching out of potassium; for the potassium content of the root bark can be brought back to normal by correcting the little-leaf with ferrous sulphate, and without applying any potassium. Further, applying 10 pounds of potassium sulphate annually to trees only slightly affected with little-leaf did not prevent them from becoming badly affected and applying as much as 7 pounds each of potassium sulphate in one year and 50 pounds each in the next to moderately affected trees did not improve them.

Eight to one hundred pounds of calcium sulphate each, applied to trees badly affected with little-leaf, did not improve them; neither did 4 to 60 pounds of magnesium sulphate.

This work could not have been done so extensively without the aid very generously given by the following county agricultural agents or assistant agents: J. P. Benson, H. P. Everett, E. L. Garthwaite, W. E. Gilfillan, N. D. Hudson, J. C. Johnston, A. A. Jungerman, H. R. Keller, M. H. Kimball, I. W. Lilley, R. D. McCallum, O. V. Patton, J. L. Quail, E. F. Serr, Enoch Torpen, and Paul Williamson.

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A Starch-Splitting Enzyme in Apple Tissues

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THE mechanism associated with the synthesis, storage, and subsequent hydrolysis of starch is usually conceded to be the enzyme, or group of enzymes, known as amylase or commonly called diastase.

Diastase is apparently one of the most widespread as well as most abundant enzymes of plants and is considered to exist in practically all living green parenchymatous tissues and in many storage organs. In spite of its wide distribution, however, it is sometimes extremely difficult to demonstrate its occurrence in certain plant structures, although the products of its action may be clearly evident.

The economic value of many fruits and vegetables depends largely upon the familiar starch-to-sugar reaction, and the researches which have been conducted in recent years have contributed much to the successful commercial handling and storage of these products. In apple fruits, starch synthesis and hydrolysis are generally recognized as important chemical processes occurring throughout the development of the apples on the tree, and later, during the period of storage.

Recently the starch conversion reaction in apples has received further consideration in the light of accumulating evidence pertaining to factors responsible for the initiation of certain functional or physiological disorders, occurring both on the tree and in storage.

In a paper given before this society last year by Fisher, Harley, and Brooks (2), a summary of results obtained from several years' investigations on the bio-chemical changes associated with the production of water-core in apples was presented. From this work it was concluded that water-core is a result of non-uniform starch conversion induced by comparatively high atmospheric temperatures. Higher soluble sugar concentrations resulting from this hydrolysis apparently set up abnormal osmotic relationships in localized tissues, resulting in the establishment of an increased turgor pressure in the affected cells. Apples directly exposed to the sun's rays, have been observed to reach temperatures of 45 to 55 degrees C. during the months of July and August at Wenatchee, Wash. Since the optimum temperatures for many plant diastases lie within this range, it seemed reasonable to suppose that a starch-splitting enzyme was responsible for this hydrolysis and could be found in apple tissues, although no report, where its presence has been demonstrated, has come to the attention of the writers.

Thatcher (5) in his study of enzymes in apples, concluded that apple juice contained no diastases. With the methods employed he was unable to detect a starch-hydrolyzing enzyme in the fruit after starch had disappeared.

Carne, Pittman and Elliott (1), in their report of studies in Australia on bitter-pit, cork, and water-core of apples, conclude

that these diseases are intimately related and are fundamentally caused by osmotic contrasts resulting from localized starch hydrolysis. However, no reference is made to the agent directly involved in this hydrolysis.

In the present work, the desirability of proving the existence of diastase in apple tissue was two-fold; first, because of its immediate relation to the problem at hand, namely, water-core, and secondly, because the results obtained might be applicable to the study of other plant tissues in which the occurrence of diastase is difficult to verify.

EXPERIMENTAL

Analogous to the results of Thatcher (5), it was found that the juice expressed from the pulp of apples in various degrees of maturity, seemed to show an absolute inability to digest starch paste as determined by the color reaction with iodine, or by measuring the reducing substances produced. Several methods, involving the treatment of apple tissue with alcohol, acetone, and ether were likewise employed, but without success. These negative results held constant throughout a long series of experiments and method modifications, the details of which would be too great in length to discuss at this time.

During the course of these experiments, however, it was discovered that when the apple seeds, which contain a very active diastase, were macerated with the pulp, the resulting extract or juice still reacted negatively in its action on starch paste. This seemed to indicate that some substance present in the pulp juice was retarding the action of the seed enzyme. Furthermore, when a few drops of apple juice were added to such powerful starch-splitting enzymes as contained in saliva and malt diastase, their action was greatly retarded or completely paralyzed. It was therefore evident, that there is contained in the press juice of apples an effective diastase inhibitor, which, when brought into contact with the enzyme, destroys its ability to act on starch paste.

Further investigations revealed that the substance or group of substances responsible for this inhibiting power was soluble in water and alcohol and was acid in reaction, for if the juice was titrated with alkalis or buffered to pH 6.00-6.80 the inhibiting effect on saliva and malt was removed. However, tests conducted with neutralized or buffered juice on starch paste still remained negative, as did also a water extract of apple tissue previously extracted with alcohol. Attempts to separate diastase from the inhibiting substance by dialysis were likewise unsuccessful.

Examination of the results secured in these experiments seemed to signify that if diastase is present in apple cells, it must either be in the form of zymogen, or its activity regulated by the protoplasm on the basis of the inactivation of the enzyme by the inhibitor, as suggested by Harvey (3). Attempts to convert the zymogen to active enzyme by the addition of various organic and

inorganic acids, bases, and salts, to extracts of apple tissue, were met at all times with failure. The hypothesis ascribing the activity of enzymes to regulation by the protoplasm, was considered too vague to have a practical working application.

The possibility of the enzyme and inhibitor existing in separate cells was also considered, but this was subsequently set aside, for, microscopic examination indicated that every cell in immature apples contained starch grains, and, since there is finally a complete disappearance of starch after maturity it would necessarily follow that the enzyme should also be present in every cell.

Apparently one hypothesis remains to account for the difficulties encountered in demonstrating an active diastase in apple tissues. According to Hofmeister (4) the enzyme, and the substrate containing the inhibitor, may be confined in different phases of the cell system, possibly separated from each other by protoplasmic layers or films.

With this theory as a basis, a series of experiments was undertaken to devise a technique whereby the diastase and inhibitor might be removed from the cell in such a state that the inhibitor would not come into contact with the enzyme in a form detrimental to its activity. The procedure involved neutralizing the inhibitor and precipitating the enzyme simultaneously with the mixing of the cell contents. This was performed by maceration of the tissue under strong alcohol which was adjusted to maintain a neutral or slightly acid reaction, by the addition of buffering salts. The resultant mixture was then filtered, the filtrate containing, among other things, the neutralized inhibitor and alcohol soluble sugars; the precipitated enzymes remaining with the residue.

Water extracts of the dried residue were found to possess the power to hydrolyze dilute starch paste as determined by the color reaction with iodine, or as measured by the amount of reducing substances produced. Further refinements of the method led to a product of greater activity, and with the procedure now employed an active starch splitting enzyme may be obtained.

The detailed steps involved are as follows: Apples are peeled and the seeds and core tissues removed. After weighing, the tissue is grated, by means of a common fine-toothed household vegetable grater, under a large volume of redistilled 95 per cent ethyl alcohol, saturated with sodium acetate. In this work the concentration of alcohol was maintained at a minimum of 80 per cent, consequently quite large volumes of alcohol were required, because of dilution by the apple juice. In earlier experiments sodium bicarbonate was selected as the neutralizing agent, but the use of this material was abandoned due to difficulties encountered in maintaining uniform hydrogen-ion concentrations. Phosphate salts seemed impractical because of their insolubilities in alcohol. Sodium acetate appears to be a very satisfactory buffering salt, as a rather uniform hydrogen-ion concentration can be maintained if

the alcohol is kept fully saturated during the macerating or grating process.

After the tissue is grated the mixture is filtered through paper with suction, on a large Buchner funnel. Following successive washings with pure 95 per cent alcohol, acetone, and ether, the residue is dried in a current of air at laboratory temperatures and under slightly reduced pressure. The resulting dry tissue is then ground to a fine powder in a mortar, extracted a second time with alcohol saturated with sodium acetate, filtered, washed again with alcohol, acetone, and ether, and dried as before.

Water extracts of this powdered tissue were found to contain an active starch-splitting enzyme, particularly when the substrate was buffered to the optimum pH for apple diastase.

By weighing out definite quantities of the apple powder prepared as described and determining its diastatic activity on the basis of fresh weight of the tissue, it was found that 10 grams of fresh tissue contained diastase capable of converting from 12 to 21 mg. of starch at 50 degree C., as measured by calculating the free reducing substances produced in terms of dextrose. The digesting mixtures were protected from contamination by the addition of toluol.

The varieties of apples which were studied and which yielded an active enzyme were Winter Banana, Winesap, Stayman Winesap, and Delicious. Active diastase was found in apples of practically all stages of maturity, ranging from quite small immature fruits from the tree, to apples which no longer contained starch grains and which were well beyond the stage of eating maturity.

Studies thus far indicate that the optimum acidity for diastatic activity of mature Delicious apples, as determined by the starch-iodine reaction, is approximately pH 5.9, at laboratory temperatures, for a period of 3 hours. For periods of 2 to 37 hours at 50 degrees C. the optimum range was pH 6.1 to 6.6. As determined by saccharification, the optimum pH at 50 degrees C. for 48 hours covered a range of 5.8 to 6.5. In these tests a solution of commercially prepared soluble potato starch was used as the substrate, and sodium acetate and acetic acid as the buffer reagents.

An interesting point in connection with the study of apple diastase, is in comparing the optimum pH at which the enzyme is active, with the acidity of freshly expressed apple juice. In one lot of rather immature Delicious apples the acidity of the juice was found to be about pH 3.8, and in commercially mature fruits about pH 4.0. Apple juice having a pH of 3.8 to 4.0 was unable to hydrolyze starch paste, whereas starch paste buffered to pH 3.8 to 4.0 was found to be feebly acted upon by the prepared enzyme of Delicious apples. This apparently indicates that the hydrogen-ion concentration alone does not entirely account for the inhibiting action of apple juice on diastase, but that in addition certain compounds such as the tannins, malic acid, etc., may act as specific in-

hibitors of the enzyme. These results also seem to lend further evidence to the hypothesis that the enzyme exists in a separate phase or compartment from the constituents of the cell which are responsible for inhibiting its action.

The application of this method for accurate quantitative measurements of diastatic activity in apples is not emphasized at this time. However, it is believed that with some refinements, this method should give satisfactory comparative results.

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Comparative Temperatures of Apples

By ARTHUR MEYER, *University of Missouri, Columbia, Mo.*

VARIETIES of apples vary in their susceptibility to sun-scald during the hot days of late summer. Is that difference due to variation in the absorption of heat, and in turn, is the latter correlated with the color of the fruit?

According to Gortner (2), "one suggestion as to a possible function is that they (*anthocyanins*) may serve to screen out the injurious short wave lengths of light.... The pigments also act as an absorber of heat rays. Leaves colored with anthocyanins may be as much as 2 degrees C. warmer than other leaves on the same plant which contain only the green pigments and which have the same light exposure."

TABLE I—HIGHEST TEMPERATURES OF APPLES ON 3 DAYS IN 1931

Varieties Listed in Order of Color Intensity	Temperature (Centigrade)			
	Aug. 28	Sept. 5	Sept. 10	Ave.
Average air temperature during test.....	27.35	34.64	34.37	
Red June.....	33.50	41.73	—	37.61 ¹
King David.....	32.00	40.16	38.82	36.99
Jonathan.....	32.80	40.90	40.21	37.97
Winesap.....	32.00	39.64	40.44	37.36
Ben Davis.....	29.80	38.38	39.26	35.85
Delicious.....	29.92	40.69	39.72	36.77
Rome.....	32.20	40.52	38.74	37.15
Grimes.....	30.60	39.72	39.74	36.69
Golden Delicious.....	30.40	39.36	40.23	36.66
Golden Winesap.....	—	40.05	40.18	40.11 ²
Average.....	31.47	40.02	39.70	37.31
Difference: Fruit temp. less air temp.....	4.12	5.38	5.33	

¹Low, being based on first two determinations.

²High, being based on last two determinations.

The writer has verified Gortner's latter statement. The red portion of a Coleus leaf was 1.6 degrees C. higher than the green portion of the same leaf. This fact suggested that the more intense the red color of an apple, the higher the temperature would be. With that idea in mind the following experiment was performed:

Apples of 10 varieties were picked from the trees, and placed on 1-inch mesh poultry wire about 15 inches above blue grass sod. The apples were kept in an exposed position, the sunlight striking the most highly colored side of each fruit during the heat of the day. The temperature was determined by placing a thermo-couple on the surface of the apple exposed to the sun's rays. An apparatus described by Miller (3) was used in making the study.

The accompanying table shows the temperatures of the varieties studied. The difference between air temperature and temperature of the fruits was not as high as stated by Brooks and Fisher (1), but it was appreciable.

The averages for the 3 days show that there was a general decline of temperature with a decrease of red color, but it can hardly be considered significant, especially in view of the fact that Ben Davis had the lowest temperature, and the Grimes and Golden Delicious were of about the same temperature as varieties carrying visible anthocyanins.

However, the varieties devoid of red coloring matter, especially the Golden Winesap, showed the most injury from the sun's rays, and some of the red fruits were exposed to the sun for 3 days without visible harm.

This indicates that apples under the same exposure have about the same temperatures, but that the anthocyanins exert a protective influence.

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Cold Storage Tests with McIntosh Under Forced Air Circulation

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THE advent of the blower and the concentration of the brine pipes into a small space in cold storage rooms has led to the question of the value of this type of refrigeration unit.

In 1929 the University of New Hampshire installed a cold storage plant which included cold storage rooms in which refrigeration is obtained by the old system where the brine pipes are placed along the walls, and by the new system where the brine pipes are concentrated in a metal case and the air circulated by means of a large motor driven fan. The air is drawn in at the bottom of the metal case up through the coils and discharged near the ceiling. The latter will be referred to as the blower type of refrigeration and the former as the coil type in this paper. The blower type room is 11.5 x 15 feet and the coil type room is 9 x 11.5 feet.

Storage tests were made in 1929-30 and 1930-31 on McIntosh apples stored under the different types of cold storage at a temperature of 31 to 32 degrees F. Firmness of the flesh, acidity, ground color, and breakdown were used as indications of the condition of the fruit. The firmness of the flesh was determined with a Magness pressure tester, the acidity in 1929-30 on the expressed juice and in 1930-31 on the apple flesh. N/10 NaOH was used for titrating with phenolphthalein as an indicator, and the acidity figure as 2/3 malic acid and 1/3 citric acid. The ground color was determined by comparison with the color chart in U. S. D. A. Bulletin 1448. Thirty apples were used in a sample.

In 1929-30 boxes of pre-cooled fruit were taken at random from the conveyor after they had been packed and placed in the different storages. In 1930-31 the fruit for storage experiments was picked from five trees, and the sample lots, consisting of 30 apples each, were made uniformly representative by selecting fruits from different parts of all the trees.

RESULTS OF TESTS

There was no significant difference in the firmness or acidity of the fruit stored in the blower or coil rooms. Fig. 1 shows the results of these tests for the season 1930-31. In 1929-30 the results were similar except that the pressure tests were 1/2 to 1 pound higher throughout the season. No differences were observed in the ground color.

The percentages of brown-core, breakdown, and decay, are shown in Table I. Brown core as described in Cornell Extension Bulletin 189, occurred first on May 20 in both lots in 1929-30, but it was considerably more serious in the fruit stored in the coil room. It did

not occur in a form which would decrease the commercial value of the fruit in either storage before June, however. Breakdown occurred first in the coil type storage August 21 in 1930.

TABLE I—PERCENTAGE BROWN CORE, BREAKDOWN, AND DECAY, IN MCINTOSH STORED AT 32 DEGREES IN COIL AND IN BLOWER TYPE OF STORAGES

Blower Room 1929-30					Coil Room 1929-30			
Date	Brown Core Slight	Brown Core Severe	Break-down	Decay Due to Mechanical Injury	Brown Core Slight	Brown Core Severe	Break-down	Decay Due to Mechanical Injury
Mar. 21.....	—	—	—	6.6	—	—	—	—
Apr. 30.....	—	—	—	—	—	—	—	—
May 20.....	13.3	—	—	10.0	40.0	—	—	13.3
June 11.....	53.3	—	—	—	76.6	3.3	—	3.3
July 2.....	56.6	—	—	—	70.0	6.6	—	3.3
July 24.....	90.0	—	—	10.0	86.6	—	—	—
Aug. 21.....	90.0	3.3	—	6.6	70.0	23.3	6.6	13.3
Sept. 12.....	—	90.0	—	—	—	93.3	3.3	—

Coil Room 1930-31					Blower Room 1930-31			
Date	Brown Core Slight	Brown Core Severe	Break-down	Decay Due to Mechanical Injury	Brown Core Slight	Brown Core Severe	Break-down	Decay Due to Mechanical Injury
Feb. 21.....	—	—	3.3	—	—	—	3.3	—
Mar. 11.....	56.6	—	—	10.0	23.3	—	—	—
Mar. 30.....	40.0	—	—	—	46.6	—	—	10.0
May 18.....	33.3	40.0	3.3	—	50.0	46.6	3.3	—
June 26.....	33.3	36.6	16.6	6.6	66.6	23.3	3.3	6.6
Aug. 22.....	20.0	13.3	33.3	13.3	57.6	38.4	19.2	—

In 1930-31 brown core occurred somewhat earlier in both storages than in 1929-30. March 11 the fruit in the coil room showed nearly $2\frac{1}{2}$ times as much as that in the blower room, and was considered serious before June 1st. Some breakdown also occurred in both lots May 18, but not of commercial significance.

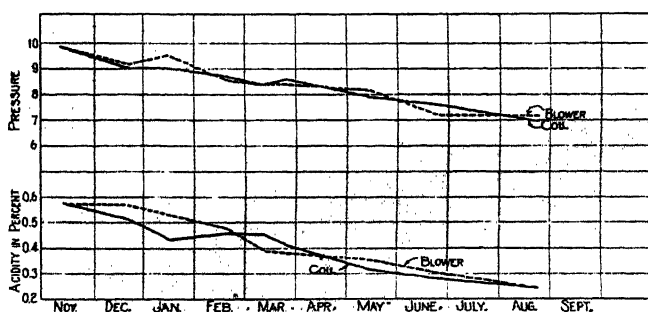


FIG. 1. Pressure tests and acidity of McIntosh apples stored in coil type and blower type cold storages 1930-1931.

The difference in the maximum and minimum air temperatures in the coil room is 5 degrees F., and the fluctuation at any one point is 3 degrees F. If we consider the optimum temperature for storing

apples is 30 to 32 degrees F. and the storage adjusted to these temperatures then the fruit in the colder part of the room will freeze, while if the temperature is adjusted so the minimum is 30 to 32 degrees then the fruit near the ceiling will be 4 to 5 degrees above the optimum. The fruit in the coil room on which the tests were made was stored in a part of the room which was nearest to 30 to 32 degrees F. The fluctuation of 3 degrees F. in the air temperature at any one point is not great enough to cause a change in temperature in the center of a packed box of apples. Where the air temperature recorded is 30 to 33 degrees the temperature in the center of the box of apples is near the maximum temperature of the air.

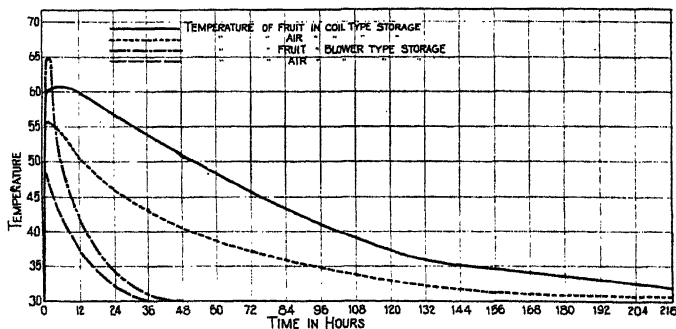


FIG. 2. Rate of cooling of fruit and air in blower type and coil type of cold storages when filled with warm fruit direct from orchard.

The difference in maximum and minimum air temperature in the blower room is 3 degrees F., and the fluctuation at one point is about 2 degrees F. The temperature within the center of a box of apples is about the maximum of the air temperature at that point. With these small variations in temperature it is not difficult to keep all the fruit in the storage at or near the temperature desired.

The comparison of the temperatures in the center of a box of apples and the air in the storage was obtained with a combination distance soil and air thermograph. The gas bulb at the end of the capillary tubing was placed in the center of a box of apples with apples in direct contact with it. The recorded temperature was considered the temperature of the fruit.

When a large quantity of fruit is to be cooled quickly and the storage room is limited the blower type of refrigeration is much more efficient than the old coil type. Fig. 2 shows the rate of cooling of the fruit when the rooms were filled with warm apples loose in boxes direct from the orchard. The fruit was piled so as to permit circulation of air between the tiers of boxes. Over 250 hours were required to cool the fruit in the center of the coil room to the air temperature of 30 degrees as compared to 48 hours in the blower room. The tem-

perature of the air in the center of the pile of fruit was determined by the use of a soil and air thermograph as stated above. If this difference in rate of cooling occurs in these small storage rooms, how much time would be required to cool the fruit in the center of some of the large commercial storages?

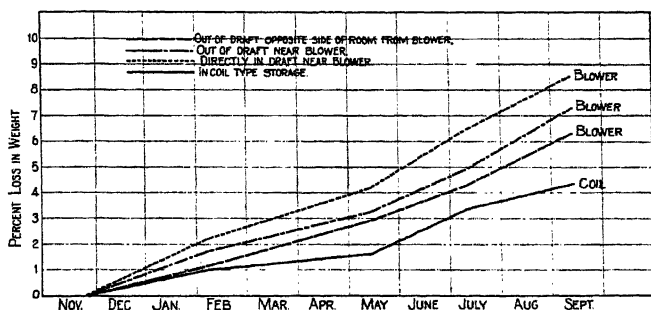


FIG. 3. Loss in weight of fruit stored in different parts of blower type cold storage and in coil type storage.

Experiments were conducted to determine if the forced circulation of the air had any influence on the loss in weight of the fruit. Three boxes of wrapped fruit were placed in different parts of the blower room, one near the blower directly in the draft, one near the blower out of the draft, and one in the opposite side of the room out of the draft. One box was placed in the coil room. Weights on the apples were taken at 6-week intervals. Results are shown in Fig. 3. The box directly in the draft lost 2 pounds in weight, the box out of the draft on the opposite side of the room from the blower 1.48 pounds, the box near the blower out of the draft 1.32 pounds, and the box in the coil room 1.20 pounds, by June 1st. Humidity in the rooms varied between 85 and 90. The loss in weight with the exception of the fruit directly in the draft is not enough to affect visibly the tightness of pack or appearance of the fruit when the crop is disposed of before June 1st.

CONCLUSIONS

The temperature variation is greater in the coil type of cold storage than in the blower type. This difference is large enough so that when the center of the room is regulated to 30 to 32 degrees F. the fruit near the coil pipes or floor is likely to freeze. The rate of cooling is much more rapid in the blower room, 250 hours being required to cool 250 boxes of apples in the coil room as compared to 48 hours in the blower room. No differences were found in pressure, acidity, or ground color in the fruit stored in the different types of storages. Brown core and breakdown was more severe in the coil room, however. Loss of weight was greater in the blower type of storage.

Some Effects of Fertilizer Upon Storage Response of Jonathan Apples¹

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A preliminary report on the effect of fertilizers upon storage quality of apples, involving 2 years' data from test plots of Jonathan, showed no significant variations in the rate of softening as measured by the pressure tester that could be attributed to fertilizer treatments (1).

Results based upon two additional seasons' work with the Jonathan and also with the Winesap are herewith reported. The observed influences of the fertilizer treatments upon the storage response of apples are two-fold, namely, the effect upon firmness of tissue at harvest and after 3 months storage at 32 degrees F as indicated by samples of comparable size, color and maturity, and by samples representative of the fruit from each plot with respect to size and color; and the effects upon Jonathan breakdown. The relation of other complicating factors such as leaf-area-fruit ratio, size of crop, and average size of individual fruits are also considered.

The plots providing the material for both the previous paper and this paper were fertilized as follows: N only, P only, K only, NP, NK, PK, and NPK. All applications were in the inorganic form, at an annual rate per tree of 1 pound actual N, 1 pound P_2O_5 , or 2.5 pounds K_2O , as the case may be.

EFFECT OF FERTILIZERS UPON FIRMNESS OF FLESH

Comparable Samples.—When samples of comparable size, color, and maturity were selected from each of the fertilizer plots on both Jonathan and Winesap apples, there apparently was no consistent measureable influence of the fertilizer treatments upon firmness of texture, as determined by the pressure tester in pounds. The results shown in Table I for the Jonathan are the averages for a 5-year period, 1927–1931 inclusive, and for the Winesap for a 3-year period, 1929–1931.

The results with such samples, show no significant differences in firmness at harvest time, or after 3 months in cold storage, between samples from various fertilizer plots and plots receiving no fertilizer. Furthermore, at time of harvest there was little difference in pressure between the fruit from season to season. After 3 months storage at 32 degrees F, however, while the pressure of each lot from the different fertilizer plots did not vary any one season, all lots varied markedly from season to season. For example, the pressure after 3 months storage was uniformly lowest with the crop of 1929 averaging less than 12 pounds. On the other hand, the average pressure of all lots was uniformly highest after storage in 1931, averaging about 15 pounds.

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The pressure was next lowest in 1931, and next highest in 1928. This indicates that with the uniform samples of the same size, color, and maturity from each plot, the climate or other environmental conditions exerted far greater influence upon firmness of flesh than did the fertilizer treatment.

TABLE I—EFFECT OF FERTILIZER TREATMENT ON FIRMNESS OF JONATHAN AND WINESAP APPLES AS SHOWN BY PRESSURE TESTER

Date	Variety	Pressure Test in Pounds			
		Average of All Trees Receiving			
		N	P ₂ O ₅	K ₂ O	Check
Harvest.....	Jonathan	15.3	15.3	15.5	15.5
Dec. 15.....		13.4	13.5	13.5	13.5
March 1.....		11.1	11.2	11.2	10.9
June 1.....		10.2	10.3	10.2	10.1
Harvest.....	Winesap	20.4	20.6	20.5	20.9
March.....		15.8	15.7	15.7	15.9
June.....		14.8	14.8	14.9	14.6

The small differences shown in the firmness of flesh of the fruits receiving N, P, and K, and no fertilizer are in agreement with the statement by Knowlton and Hoffman, (2) "Apples of the varieties (Stayman and Black Twig) uniform in size and color will probably show the same firmness, as measured by the pressure tester, regardless of the fertilizer given the trees from which they were picked."

Representative Samples.—It has been determined, however, that the fertilizer application does affect the size, degree, and per cent of overlaying red color and the time of maturity. Hence, to this extent the firmness of the fruit as measured by the pressure tester in pounds on representative samples from the plots, is affected in conformity with the preceding factors. For example, fruit from the nitrogen-bearing fertilizer plots is larger and less highly colored than that from the check and non-nitrogen plots.

TABLE II—AVERAGE PRESSURE TEST OF APPLES OF DIFFERENT SIZES

Size of Fruit per Box	No. Tests	Average Pressure Test
100's.....	387	14.7
125's.....	1072	14.9
150's.....	786	15.0
175's.....	912	15.6
200's.....	729	15.8
225's.....	347	15.6

The smaller and more highly colored fruit averaged firmer as determined by the pressure tester, than did the larger, less highly colored fruit. The results of a number of pressure tests on the effect of size on the firmness of fruit are shown in Table II. Pressure tests were made on three sides of each apple.

The apples used for tests in Table II were of the extra fancy grade, ranging in total red color from 65 to 100 per cent.

Comparative pressure tests were made after retention for 3 months in cold storage at 32 degrees F. Two methods of obtaining fruit samples from the trees of each plot were used. For the first, uniform samples of extra fancy color and grade with a size range of from 113 to 150 specimens per box were obtained. For the second, representative samples of "tree run" fruit including extra fancy, fancy and "C" grades and with size range of 100 to 225 specimens per box were obtained. The average color, size, and firmness of flesh of the fruit of the Jonathan variety from each plot of the two types of samples are shown in Table III.

TABLE III—COMPARATIVE PRESSURE TESTS BETWEEN SELECTED SAMPLES AND REPRESENTATIVE SAMPLES FROM THE SAME TREES AND PLOTS AFTER 3 MONTHS IN COLD STORAGE

Fertilizer Treatment	Selected Samples				Representative Samples		
	Ave. Color per Plot	Ave. Size Fruit	No. Tests	Ave. Pressure Test	Ave. Size Fruit	No. Tests	Ave. Pressure Test
N.....	72.6	125	90	14.7	188	90	14.9
NP.....	76.9	125	90	14.6	188	90	15.2
NK.....	72.9	138	90	15.2	175	90	15.3
NPK....	73.0	138	90	15.1	175	90	15.3
Check...	88.8	125	90	15.1	188	90	15.8
P.....	92.3	163	90	15.3	188	90	15.6
K.....	93.2	150	90	15.5	200	90	16.0

The highest average pressure tests was with fruit from the plot receiving potassium only and which produced the smallest and most highly colored fruit. The lowest pressure tests were from the plots receiving nitrogen either alone or in combination with the other elements such plots producing the largest and lowest colored apples. The difference in pressure tests between selected samples and representative samples is not marked, however, varying from .1 to .7 lbs. This difference is probably due to differences in size and color of fruit as brought about by the fertilizer treatments.

EFFECT OF FERTILIZERS ON JONATHAN BREAKDOWN

Studies were continued on the effect of fertilizers upon Jonathan breakdown since the preliminary report made in 1929 (1). The larger sized fruits on the tree were found to be more subject to physiological breakdown than the smaller sized fruits. Magness, Overley, and Luce, (3), by growing apples with a different number of leaves per fruit showed that "the greater the leaf area per fruit, the greater the total size of the fruit procured, although the increase in size of fruit was not in proportion to the increased foliage." With the application of fertilizers that stimulate tree growth, leaf area is increased. The results of controlled² leaf area tests on Jonathan trees in 1930, when apples were grown with a varying number of leaves per fruit, showed that the per cent of breakdown increased with the increased leaf area per fruit. The tests were conducted on good,

²Leaves and fruit thinned to required ratio and branches ringed according to method reported by Magness, Overley, and Luce (3).

vigorous, heavy-producing Jonathan trees that had been fertilized for three seasons with sulfate of ammonia, 5 pounds per tree. The per cents of breakdown after 3 months storage at 32 degrees F for the different leaf areas per fruit were as follows: 10 leaves per apple, no breakdown; 20 leaves per apple, no breakdown; 30 leaves per apple,

TABLE IV—AVERAGE NUMBER OF APPLES HARVESTED PER TREE IN THE DIFFERENT FERTILIZER PLOTS

Year	N	P	K	Check	PK	NPK	NP	NK
1928.....	1701	1533	1484	1911	1551	1448	1589	1005
1929.....	2104	2019	2635	1707	2539	2343	2756	2603
1930.....	3464	1651	2224	2533	2392	2593	3155	3081
1931.....	2556	1372	1498	1821	2024	2164	2169	2175

6 per cent breakdown; 40 leaves per apple, 18 per cent breakdown; 50 leaves per apple, 60 per cent breakdown. Since with the greater leaf area per fruit, the larger the average size of each specimen, these results were in agreement with Palmer (4), who reported, "From the results secured it is evident that even with apples picked from the same tree on the same date the large sizes were more subject to breakdown than the medium or small sizes." Breakdown in Jonathans is found generally in apples packing 138's per box and larger. It is possible, however, that with the larger leaf areas per fruit some other predisposing condition than fruit size increase results that makes the fruit more likely to develop Jonathan breakdown in storage.

The possible ratio of leaf area per fruit that annually existed on the trees of each plot is shown in Tables IV and V by the total number of fruits harvested per tree and by the average size of each fruit. When the average number of harvested fruit is small and the average fruit size large the leaf area per fruit would tend to be large.

The average annual size of the individual specimens from the trees of each fertilizer plot is shown in Table V. When the average number of specimens per 42-pound standard apple box is low, the fruit is comparatively large.

TABLE V—AVERAGE ACTUAL NUMBER OF APPLES PER STANDARD 42-POUND BOX NET WEIGHT

Year	N	P	K	Check	PK	NPK	NP	NK
1928.....	157	178	176	163	169	157	157	143
1929.....	142	158	167	143	156	151	146	145
1930.....	154	174	184	152	179	144	149	142
1931.....	149	181	190	162	164	169	147	143

One box of apples from each tree in each plot was selected as uniformly as possible for size (125 per box) and color (75 to 100 per cent red color) and placed in cold storage at 32 degrees F within 24 hours from the time of picking. The fruit from all plots was harvested within a 48 hour period each year.

The per cent of Jonathan breakdown observed in Jonathan apples from the different fertilizer plots for the crops of 1928, 1929, 1930, and

1931, when examined on December 15 after removal from 32 degrees F are shown in Table VI.

TABLE VI—AVERAGE PER CENT BREAKDOWN WITH COMPARATIVE SIZE APPLES FROM THE DIFFERENT FERTILIZER PLOTS

Year	N	P	K	Check	PK	NPK	NP	NK
1928.....	8.7	4.3	1.9	8.0	4.3	6.3	8.7	9.4
1929.....	40.2	30.9	18.8	25.6	17.6	17.9	22.2	15.3
1930.....	2.5	3.2	1.5	4.8	.9	5.2	5.3	3.4
1931 to Dec. 15	0	2.5	.8	3.3	2.5	4.2	2.5	0
Average...	15.3	10.3	5.7	10.2	6.4	8.5	9.8	7.0

The results of these tests show that breakdown varied with different seasons regardless of fertilizer treatment. This is in agreement with Palmer's results in his Jonathan breakdown studies, which "indicate that losses from breakdown are much more serious some seasons than others."

Analysis of data shown in Table VI indicates that potash used either alone or in combination with nitrogen and phosphorus may reduce the per cent of physiological breakdown in Jonathan apples. Furthermore, applications of nitrogen alone apparently tended to result in an average increased percentage of Jonathan breakdown, but this seemingly was because of the excessively high percentage of breakdown from the nitrogen plots in 1929. Nitrogen, alone or nitrogen with potash may, however, tend to increase Jonathan breakdown, first by giving a larger leaf-fruit ratio, and second, by giving more large size specimens. Therefore, the differences in breakdown shown between the various fertilizer plots may be due to variations in the leaf area fruit ratio or in size of fruit as shown in Tables IV and V, or some other factor such as climate, rather than the direct effect of fertilizers.

TABLE VII—PER CENT PHYSIOLOGICAL BREAKDOWN AS AFFECTED BY SIZE AND LOAD OF FRUIT ON TREE

Tree No.	1929			1930			1931		
	Size Fruit	No. Fruits per Tree	Per cent Break-down	Size Fruit	No. Fruits per Tree	Per cent Break-down	Size Fruit	No. Fruits per Tree	Per cent Break-down
1	146	2573	4.3	119	2327	3.4	117	2712	0
2	148	2447	0	133	3545	3.4	115	1952	0
3	144	2625	12.0	117	1937	11.0	106	805	50.0

It is of interest to note that during the season of 1929 all plots showed far more breakdown than was exhibited any other season. As previously stated, the fruit harvested this year averaged lower in firmness of flesh after three months storage than was the case during any of the other three years. Gourley and Hopkins (6) also reported that under Ohio conditions, the 1929 crop Jonathan and Stayman Winesap was severely affected with a similar trouble.

As further evidence of the relation of size of specimens and load of fruit, whether influenced by fertilizers or other factors, to the susceptibility to Jonathan breakdown, data are available from another plot where one pound of nitrogen per tree was annually applied for three years. The data are shown in Table VII.

Neller (4) found that fruit showing Jonathan breakdown was higher in per cent of dry matter and sucrose. Magness, Overley and Luce (3) found that fruits from branches with large leaf area were higher in total sugars and dry matter than fruit from branches with a small leaf area.

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Orchard Variability in Maturing the Italian Prune¹

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STUDIES of changes during the ripening process of the Italian prune have been previously² made in Oregon and Idaho (2, 3). These changes were measured by noting at regular intervals the firmness, color, and flavor of the fruit, and the acid content and density of its juice. Density of the juice as determined with the Balling hydrometer was used as an index of the sugar content. As a measure of maturity changes it was found that sugar content was more variable than firmness while the acid content determinations varied too much to be reliable (2, 3). Allen, Magness, and Haller (1) also found a similar variation in hydrometer readings as a maturity test for California plums.

In this study maturity changes of prunes in different orchards were compared. The principal measures used were firmness and sugar content. Firmness was determined by the standard method of using the U. S. type pressure tester equipped with a 5/16-inch plunger. Two pressures were taken on each prune, one on each cheek. Prunes for testing were picked at random, one from the south and one from the north side of each of 10 trees. The 40 firmness tests made on the 20 prunes were averaged. The probable errors³ of these tests approximated ± 0.11 pounds and indicated an inaccuracy of not more than ± 0.33 pounds in an orchard firmness measure at any one time.

The sugar content of the expressed juice was determined in 1930 by the use of the Balling hydrometer. In 1931 the sugar content was determined by measuring the refractive index with the Zeiss refractometer. The juice which collected from each prune on the tester while taking the pressure test was used as a sample for each fruit. This juice may not be an average portion for the entire prune but was a consistent sample from each fruit for comparison.

The average of the results of 20 tests on as many prunes was considered to be the sugar content for the sample. The probable errors of the various tests, ranging around ± 0.254 per cent, indicated for comparisons an inaccuracy of not more than ± 0.76 per cent. Sugar content tests by this method, like the hydrometer tests, as mentioned in the second paragraph, were more variable than the pressure tests as a measure of progressive maturity changes.

A survey was made previous to the time of harvest of the changes in firmness and sugar content of the Italian prune in several orchards in southern Idaho in 1930 and 1931. The time required in 1931 for the fruits to soften from 14.5 pounds to 12.2 pounds in firmness

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²Formula used P. E. M. = $\frac{6745}{\sqrt{n}} \times \sqrt{\frac{\sum D^2}{n}}$

varied in different orchards from 6 to 13 days (Graph A), averaging about 9.2 days. They therefore softened at the average rate of 0.25 pounds per day. During the similar period of 1930, they softened at the average rate of about 0.30 pounds per day.

TABLE I—VARIATIONS IN FRUIT MATURITY BETWEEN ORCHARDS; (1) IN FIRMNESS AT A CONSTANT SUGAR CONTENT, AND (2) IN SUGAR CONTENT AT A CONSTANT FIRMNESS

Orchard No.	1930				1931				
	At 10.2 lbs. Firmness		At 16 Per cent Sugar content		At 12.2 lbs. Firmness			At 17 Per cent Sugar Content	
	Date	Sugar Content (Per cent)	Date	Firmness (Lbs.)	Date	Sugar Content (Per cent)	Flavor ¹	Firmness (Lbs.)	Flavor ¹
1	—	—	—	—	8-28	19.3	Good	—	—
2	—	—	—	—	8-27	19.0	Fair	14.6	Sour
3	—	—	—	—	8-23	17.3	Mildly sour	13.1	Mildly sour
4	—	—	—	—	8-27	18.4	Fair	14.4	Mildly sour
5	—	—	—	—	8-30	18.1	Fair	13.1	Mildly sour
6	8-29	16.0	8-29	10.2	8-30	16.8	Mildly sour	11.9	Fair
7	—	—	—	—	9-1	19.6	Fair	14.8	Sour
8	9-2	15.8	9-4	10.0	8-29	17.2	Fair	12.2	Fair
9	—	—	—	—	8-28	18.0	Fair	14.3	Mildly sour
10	8-25	15.5	8-29	9.7	9-1	17.4	Fair	12.7	Fair
11	9-15	18.5	9-1	12.6	9-4	18.8	Fair	13.8	Mildly sour
12	—	—	—	—	9-4	19.5	Good	14.5	Mildly sour
13	—	—	—	—	9-1	17.7	Mildly sour	13.8	Mildly sour
14	9-8	18.6	8-25	14.3	9-1	20.0	Good	16.2	Sour
15	9-3	17.4	8-27	11.6	9-5	17.8	Fair	14.4	Fair
—	9-6	14.7	9-9	8.8	—	—	—	—	—
—	9-24	18.1	—	—	—	—	—	—	—
—	8-25	15.4	8-28	8.5	8-26	17.7	Fair	—	—
—	—	—	—	—	9-1	18.1	Mildly sour	14.6	Mildly sour
—	—	—	—	—	8-31	17.7	Mildly sour	—	—

¹Good flavor—ripe enough to eat out of hand.

Sour flavor—too green and insipid to eat out of hand.

The sugar content increased at the average rate of 0.19 per cent per day in 1931 and in 1930 of about 0.26 per cent per day. Graph B shows that the prunes in some orchards contained as much as 2.9 per cent more sugar when they reached a firmness of 14.5 pounds than in others. At 12.2 pounds firmness, the maximum recommended for picking, the variation between orchards of 16.9 to 20.0 per cent in sugar content (Graph B, Table I) was fully as great. In 1930 at 10.2 pounds firmness (Table I), the sugar content varied from 15.4 to 18.6, a difference of 3.2 per cent. Consequently, when the fruits in the vari-

ous orchards reached a constant sugar content, their firmness varied. This was true during both years (Table I).

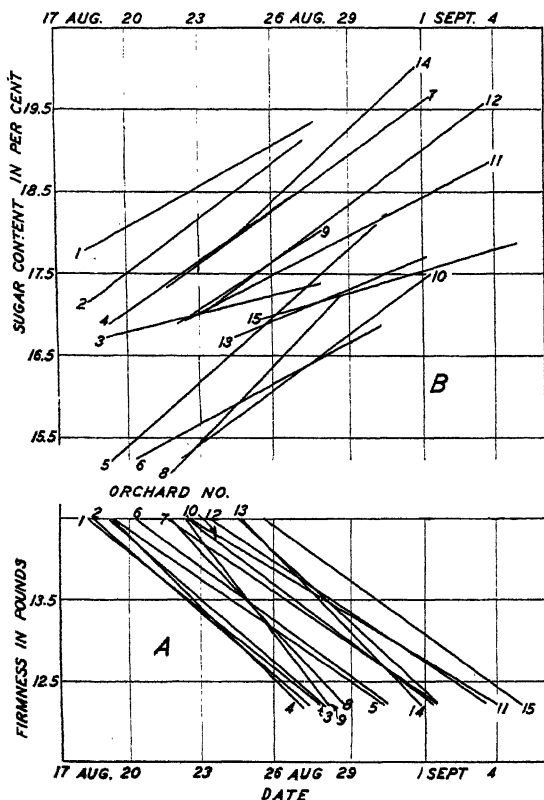


FIG. 1. Orchard comparison of maturity changes in the Italian prune in 1931. The stage of maturity shown is that while softening from 14.5 pounds to 12.2 pounds, as measured by the U. S. Pressure Tester. Graph A shows the dates that these firmnesses are reached and the average rate of softening for each orchard. The sugar content at the respective periods and the average rate of increase for each orchard are shown in B.

The fruits which softened early in some orchards were high in sugar while in other orchards the sugar content was low (Graph B). The date of softening then did not seem to be the factor affecting the amount of sugar present. An orchard showing high sugar content early in the test usually remained high and the one low in sugar usually remained low throughout the period tested. The determining factor was present before the tests were started so further studies of this are planned. It was noted, however, that irrigation checked and

sometimes even stopped the increase in sugar concentration of the juice. Since the prunes increased rapidly in size during this period it seems that the double increase of water and sugar content held the percentage low rather than stopping the formation and storage of sugar.

TABLE II—PRUNE SAMPLES FROM VARIOUS ORCHARDS CLASSIFIED ACCORDING TO FLAVOR, FIRMNESS, AND SUGAR CONTENT

Flavor	Classification as to Sugar Content and Flavor of Prunes in Orchards at the same Firmness Maturity					Classification as to Firmness and Flavor of Prunes in Orchards at the Same Sugar Content Maturity					
	Sugar Content (Per cent)					Firmness (Pounds)					
	16-16.9	17-17.9	18-18.9	19-19.9	20-20.9	11-11.9	12-12.9	13-13.9	14-14.9	15-15.9	16-16.9
Sour.....	—	—	—	—	—	—	—	—	2	—	1
Mildly sour.....	1	3	1	—	—	—	—	4	4	—	—
Fair.....	—	4	4	2	—	1	2	—	1	—	—
Good.....	—	—	—	2	1	—	—	—	—	—	—

It has been known for some time that prunes on an individual tree vary in softness (3). The soft prunes are generally considered to be sweeter and riper than the firm ones since they do not hold up so long for market. This year 110 prunes were picked from one tree and tested the same day for firmness and sugar content. The correlation of $+0.16 \pm 0.06$ between firmness and sugar content of these prunes showed that, contrary to expectations, the soft prunes did not contain a higher percentage of sugar than did the firm prunes. Similar results were obtained when a sample of 40 prunes from as many trees was tested. The correlations of $+0.844 \pm 0.022$ between flavor and sugar content and of -0.850 ± 0.021 between flavor and firmness indicate that one change affects flavor about as much as the other. Acidity changes parallel firmness to a large degree, which probably explains the high relationship between firmness and flavor. Table I shows the 1931 variations in flavor of prunes from the different orchards with the same firmness and different sugar contents and with a constant sugar content and varying firmness. In the former case, for instance, the mildly sour prunes have a lower sugar content than the prunes with a good flavor. In the latter case the sour prunes are firmer than those having a fair flavor. This is shown more clearly in Table II. When either is constant the variation of the other affects the flavor generally. Since firmness is a measure of handling qualities, it therefore determines the time of harvest for fresh fruit shipment (2, 3). These data indicate that at the recommended picking firmness the fruit varies in sugar content and likewise in flavor. The data listed here and in Idaho Bulletin No. 167 (3) show that the sugar content varies from year to year as well as between orchards at any one stage of firmness. It is therefore concluded that in some seasons and in some orchards fruit never reaches at any maturity the high quality and high sugar content that it does in others.

It seems that these variations may also affect grades of prunes when dried and graded according to the flotation method recommended by Weigand and Bullis (4, 5). Further knowledge of the causes of these variations should offer an opportunity to improve the general quality of fruit produced.

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The Respiration of Some Fruits in Relation to Temperature

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IN connection with storage studies on strawberries, peaches, and some citrus fruits the respiration rate of the fruit at different temperatures has been determined. While the storage studies have not been completed it seemed desirable at this time to present the results of some of the respiration studies.

MATERIAL AND METHODS

The apparatus used was a modification of that described by Magness and Diehl (4) with which the O_2 consumed as well as the CO_2 evolved can be measured. A description of the apparatus as modified is to be published soon in *Science*.

The strawberries for these investigations were obtained from the field of a commercial grower located a few miles from Washington, D. C. The berries were picked in the morning and taken immediately to the cold storage laboratory at Arlington, Va. The overripe, immature, and unsound berries were sorted out and the remaining berries were weighed and placed at the different temperatures where they were left overnight to come to the temperature of the room. The fruit was then placed in the desiccators and respiration rate determinations started. The results presented in Table I are the average of three runs of 12 hours each with duplicate determinations at each temperature except 80 degrees, where only one desiccator was available. The amount of fruit used varied from 2 kilograms per desiccator at 32 degrees F. to 200 grams at 80 degrees.

The peaches were obtained from a commercial orchard near Leesburg, Va. The fruit was picked in the morning and taken immediately to the cold storage laboratory where it was treated similarly to the strawberries. The peaches were picked during the commercial picking season and their firmness as indicated by pressure test using a 5/16-inch diameter plunger was as follows: Carman 9.7 pounds, Belle 12.5 pounds, Elberta 5.5 pounds, and Hale 9.1 pounds. The fruit designated as Hale was obtained as Hale but its identity has been questioned by H. P. Gould and others. The amount of fruit used varied from about 2 kilograms at 32 degrees to about 500 grams at 80 degrees. The results presented in Table I are averages of duplicate determinations at each temperature and usually of four runs of 24 hours each. The oranges and grapefruit from Florida and the lemons and oranges from California were shipped by express directly to Washington, D. C., so that considerable time elapsed from the time of picking before the respiration rate determinations were started.

The fruit was otherwise treated similarly to the peaches and strawberries. The results given in Table I are averages of two or more determinations at each temperature and usually for a period of 4 days.

The respiration rate at any temperature cannot be given accurately without specifying the time concerned as the rate changes considerably with time particularly at the higher temperature. In the case of the strawberries there was an increase in respiration rate with time at all temperatures except 32 degrees F. during the three 12-hour periods. The increases were relatively slight at the lower temperatures but quite pronounced at 70 and 80 degrees. At 40 degrees, for example, Chesapeake strawberries increased from 20.4 to 22.9 mg. CO₂ per kg. hr., while at 80 degrees they increased from 148.5 to 180.6 CO₂ per kg. hr.

With the four varieties of peaches studied there was little or no change in rate at 32 and 40 degrees F. At the higher temperatures there was a gradual increase in rate with time except for Carman at 80 degrees, where there was a decrease from 106.2 on the first day to 94.7 mg. CO₂ per kg. hr. on the fourth day.

The rate of respiration of Eureka lemons was practically constant at 32, 40, 60 and 70 degrees F., with a gradual increase at 50 degrees, a decrease at 80 and 90 degrees and an increase at 100 degrees. The respiration rate of Navel oranges was constant at 32 degrees, increased at 40 and 50 degrees and decreased at temperatures of 60 degrees and above. There was little or no change in rate of respiration of Florida oranges at 32, 40 and 50 degrees with a slight increase at 60 degrees and a slight decrease at 70 and 80 degrees and a rapid decrease at 90 and 100 degrees. Florida grapefruit showed practically no change in rate at 32, 40 and 50 degrees, a gradual decrease at 60, 70 and 80 degrees, and a rapid decrease at 90 and 100 degrees.

The respiration data of the strawberries (Table I) are presented for Howard 17 (Premier) only. At all temperatures the rate of respiration of Howard 17 was 25 to 30 per cent greater than that of Chesapeake. These rates approximate those given by Gore (1) and Overholser, Hardy, and Locklin (6) but are less than half as great as those given by Gerhart (2).

The respiratory ratio ($\frac{\text{cc CO}_2}{\text{cc O}_2}$) indicates the type of material being respired. The complete oxidation of hexose sugars gives a ratio of 1 while complete oxidation of citric or malic acid gives a ratio of 1.33. A ratio greater than 1.33 in fruits would indicate intramolecular respiration. With both of the strawberry varieties studied the respiratory ratio was about 1.3 at most of the temperatures, indicating acid as the material being respired.

The respiration rate of Belle and Hale peaches was very similar to that of Elberta (Table I). The rate for Carman was considerably higher particularly at the lower temperatures and varied from 6.2 mg. CO₂ per kg. hr. at 32 degrees F. to 102.1 mg. at 80 degrees. There were no consistent changes in respiratory ratio with temperature. The

respiratory ratio of Carman was about 1 at the different temperatures indicating sugar as the material being respired. The ratio of Belle varied from 1 to 1.15 while the ratio of Elberta and Hale varied around 1.15.

TABLE I—THE RESPIRATION RATE AND RESPIRATORY RATIO OF SOME FRUITS IN RELATION TO TEMPERATURE

Howard 17 Strawberries (1930)					Elberta Peaches (1931)		
Temperature		Mg CO ₂ per Kg. Hr.	Cc O ₂ per Kg. Hr.	CO ₂ O ₂ Ratio	Mg CO ₂ per Kg. Hr.	Cc O ₂ per Kg. Hr.	CO ₂ O ₂ Ratio
°F	°C						
32	0	17.3	7.2	1.23	3.84	1.80	1.10
40	4.4	30.0	11.6	1.34	6.54	2.72	1.23
50	10.0	59.5	23.5	1.29	15.7	6.72	1.18
60	15.5	87.0	34.1	1.29	34.3	15.4	1.15
70	21.1	137.1	52.5	1.33	61.3	26.6	1.18
80	26.7	211.1	71.3	1.51	89.8	30.1	1.56
Seedling Grapefruit (Florida) (1929-30)					Eureka Lemons (California) (1931)		
32	0	2.07	1.38	0.77	2.65	1.09	1.24
40	4.4	4.86	2.23	1.13	3.70	1.56	1.20
50	10.0	6.92	2.80	1.25	10.5	5.85	0.92
60	15.5	12.6	5.35	1.19	13.5	6.98	1.00
70	21.1	16.0	6.48	1.24	18.6	9.98	0.95
80	26.7	19.0	6.64	1.45	28.2	15.5	0.93
90	32.2	27.5	8.80	1.60	40.7	17.4	1.20
100	37.7	51.4	13.2	1.96	80.2	30.0	1.36
110	43.3	81.6	26.0	1.59			
Navel Oranges (California) (1931)							
32	0	4.07	1.48	1.37			
40	4.4	6.35	2.68	1.21			
50	10.0	13.5	6.24	1.10			
60	15.5	22.7	11.1	1.05			
70	21.1	27.3	12.5	1.10			
80	26.7	36.4	13.8	1.36			
90	32.2	47.4	17.0	1.43			
100	37.7	103.0	23.5	2.24			

Of the citrus fruits studied the seedling grapefruit from Florida had the lowest respiration intensity with the oranges considerably higher than the lemons. The data for the seedling oranges from Florida are not presented but the respiration rates were similar to those of the Navel oranges from California except at 32 and 100 degrees F. where the rate of the Navel oranges was considerably higher. The respiratory ratios of the Florida oranges were very similar to those given for grapefruit and indicate in both cases considerable intramolecular respiration at temperatures of 90 degrees and above. The ratios of the California oranges and lemons differ from those of the Florida oranges and grapefruit in that they are relatively high at the lower temperatures with the minima at 50 to 70 degrees. No intramolecular respiration was shown by the lemons but the Navel oranges indicate considerable intramolecular respiration at 100 degrees.

TABLE II.—TEMPERATURE COEFFICIENTS (Q_{10}) OF RESPIRATION RATE OF FRUITS

Temp. Range (°F.)	Strawberries		Peaches				Lemons		Oranges		Grapefruit	
	Howard 17 Q_{10}	Chesapeake Q_{10}	Carman Q_{10}	Belle Q_{10}	Elberta Q_{10}	Hale Q_{10}	Cal. Eureka Q_{10}		Cal. Navel Q_{10}	Fla. Seedling Q_{10}	Fla. Seedling Q_{10}	
32-50	3.45	3.65	3.05	3.85	4.10	4.80	3.95		3.30	3.95	3.35	
42-60	2.40	2.60	3.80	4.00	4.05	3.20	2.70		2.90	2.70	2.50	
52-70	2.10	2.05	2.95	3.05	3.15	3.00	1.70		1.80	2.15	2.00	
62-80	2.20	2.20	2.10	2.05	2.25	2.15	1.95		1.55	1.60	1.45	
72-90	—	—	—	—	—	—	2.00		1.60	1.50	1.65	
82-100	—	—	—	—	—	—	2.60		2.70	1.85	2.45	
92-110	—	—	—	—	—	—	—		—	1.95	2.50	

The change in the rate of a reaction with temperature is frequently expressed by Van't Hoff's temperature coefficients (Q_{10}). This expresses the number of times the rate is multiplied by a 10 degrees C. (18 degrees F.) rise in temperature. A temperature coefficient of 2 or above is considered characteristic of chemical processes while a coefficient of 1.5 or less is characteristic of physical processes. While respiration is fundamentally a chemical process it may be limited by physical processes such as the diffusion of gases to and from cells. The temperature coefficients of the fruits studied are shown in Table II at different temperature ranges of 18 degrees F. These coefficients are based on the respiration rate as measured by the CO_2 evolved. In general the temperature coefficients of all the fruits decreased at the higher temperature ranges (Table II) with the minimum coefficients at temperature ranges of 52 to 70 degrees or 62 to 80 degrees. With the citrus fruits, where higher temperatures were used, the coefficients increased at the higher temperatures. Of the fruits studied peaches had the highest temperature coefficients. Thus at 70 degrees the respiration rate of the strawberries, oranges, lemons, and grapefruit was 7 to 8 times that at 32 degrees, while with Belle, Elberta, and Hale peaches the rate was 14 to 16 times as great at 70 degrees as at 32. With Carman peaches the rate was 11.5 times as great at 70 as at 32 degrees.

DISCUSSION

As the respiration rate is a measure of the rate of metabolism it should, theoretically, be an index to the rate of deterioration or storage life of a product. Practically it seldom is, as the storage life particularly at high temperatures is usually limited by decay and at low temperatures may be limited by physiological changes which may not be related to respiration. Magness, Haller, and Diehl (5) found that the rate of respiration of apples at different temperatures was closely proportional to the rate of softening. In general, the same relationship holds for peaches except that with peaches the storage life at the low temperatures is not as long as the low rate of respiration and softening would indicate since certain changes take place at the low temperatures, so that the fruit does not ripen normally and with good quality when removed to higher temperatures.

The respiration rate and particularly the respiratory ratio may give an indication of the type of reaction taking place in the fruit and may be to some extent a measure of deterioration in dessert quality and food value. Thus at 90 degrees F. and above, the respiratory ratio of the oranges and grapefruit would indicate intramolecular respiration with the probable formation of alcohol or aldehydes. The CO_2/O_2 ratio of oranges and grapefruit from Florida would indicate that sugar was being respired at 32 degrees while both sugar and acid were respired at temperatures of 50 to 80 degrees. This is not in accord with the analyses of Hawkins (3) who found that the acid of Florida

grapefruit decreased at 32 degrees and that the sugar content decreased at 70 degrees. The oranges and lemons from California indicated by their respiratory ratio a loss of acidity at 32 degrees and a loss principally of sugar at 50 to 70 degrees. With strawberries and peaches there was little indication of a difference in the material respired at different temperatures.

While at low temperatures the loss of material by respiration is relatively slight, at high temperatures it may become quite significant. Thus at 80 degrees F. the loss of citric acid in the strawberries would be 403. mg. from Howard 17 and 323 mg. from Chesapeake per 100 grams of fruit per day assuming that the CO_2 evolved was due to the complete oxidation of acid as the respiratory ratios would indicate. This would amount to at least 25 per cent of the total acidity normally present in these varieties of strawberries at picking time. Assuming complete oxidation of citric acid at 80 degrees the other fruit would have used 160 to 195 mg. per 100 gm. per day in the case of peaches, 67 to 70 mg. with the oranges and 54 and 36 mg. with the lemons and grapefruit respectively. The complete oxidation of sugar would give figures about 85 per cent of the amounts given for citric acid. In the case of Carman peaches and Eureka lemons the CO_2/O_2 ratios would indicate sugar as the material of respiration while both sugar and acid were indicated for Belle and Hale peaches.

The heat of respiration of rapidly respiring fruit such as strawberries may become a significant factor in their refrigeration. Thus at 80 degrees F. the heat of respiration of Howard 17 strawberries would amount to 46,442 B. T. U. per ton of fruit per day which is sufficient to melt 322.5 pounds of ice. This computation was made on the assumption that the CO_2 liberated was due to the complex oxidation of dextrose. Complete oxidation of citric acid would give off 70 per cent as much heat as dextrose. Gerhart (2) computed from his respiration data that a carload of Missionary berries weighing 4,672 pounds would melt 127.5 pounds of ice per hour at 50 degrees F. On the same basis the Howard 17 berries, as determined herein, would melt only 8.8 pounds of ice. In a letter from Gerhart he states that his figures for the heat of respiration are about six times too high due to an error in calculation. At 32 degrees the heat of respiration of Howard 17 strawberries was calculated to be 3,806 B. T. U. per ton per day which would melt 26.4 pounds of ice. The heat of respiration of Elberta peaches at 80 degrees was 19,756 B. T. U. per ton day or sufficient to melt 137 pounds of ice while at 50 degrees it was 3,454 B. T. U. and at 32 degrees it was 845 B. T. U. The heat of respiration of Navel oranges was 8,008 B. T. U. at 80 degrees, 2,970 at 50 degrees and 895 at 32 degrees. The grapefruit had the lowest respiration rate and the heat of respiration was 3,520 B. T. U. per ton day at 80 degrees, 1,518 at 50 degrees and 455 at 32 degrees. At 32 degrees the heat of respiration of the grapefruit would melt only 3.2 pounds of ice per ton day.

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Studies in the Transpiration Rate of Apple Varieties^{1,2}

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THE economical utilization of soil moisture has long been recognized as a matter of vital importance in apple production. The fruit grower in non-irrigated districts has generally adopted certain well-known cultural practices designed to conserve soil moisture without consideration of the plant itself as a factor in water economy. It is generally recognized that species of plants vary in their water requirements, but practically no studies have been made on the water requirements of varieties of fruit plants.

Observations on the behavior of non-irrigated apple varieties during a week of hot dry weather at the end of a rainless summer in the Willamette Valley of Oregon showed certain varietal differences in resistance to drought, which apparently were due either to varietal differences of root development or to transpiration rate. Apparently, Knight (1) of the East Malling Research Station is the only investigator to study the transpiration rate of apple varieties. He reports that apple scion varieties have a definite rate of transpiration, but he does not furnish any data to support this conclusion.

This paper is a preliminary report on studies in the transpiration rate of apple varieties which were conducted at Oregon State College during the summer of 1930. The purpose of the study was to determine the relative transpiration rate under atmospheric conditions favoring high transpiration. In apples as in many other plants, the transpiration rate assumes importance only when it is high enough to cause a deficiency of water in the plant.

MATERIALS AND METHODS

After preliminary studies with various methods of measuring transpiration, a battery of 40 burette-potometers was set up in an empty section of the college greenhouse, where atmospheric conditions favored a high rate of transpiration similar to that found out of doors on a hot, dry day.

Four varieties were compared in each experiment. Ten shoots, typical of each variety, uniform in size, and free from insect and spray injury, were selected from shoots cut at random from all parts of the trees. They were cut under water with a sharp knife, connected to a continuous column of water in the burette-potometer, and allowed

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to transpire an hour or more before starting measurement of the water transpired. Distilled water was used in all potometers. At the end of each experiment, the leaf area of each shoot was determined by carefully tracing each individual leaf with a planimeter. The evaporating power of the air was determined by the use of two white spherical atmometers located at each end of the line of potometers. Temperature and relative humidity were determined at convenient intervals by means of a sling psychrometer.

TABLE I—SUMMARY OF FIRST TRANSPIRATION STUDY OF FOUR APPLE VARIETIES

Variety	Total Number Shoots	Total Number Leaves	Total Leaf Surface (Sq. Cm.)	Total Water Used 1-24 Hours (Cc.)	Average Water Used per Sq. Cm. 1-24 Hrs. (Cc.)	Relative Ranking (Per cent)
Starking.....	14	320	7667	2516.5	0.328	100.0
Baldwin.....	11	182	6789	2032.8	0.299	91.2
Arkansas Black....	11	203	7658	1933.6	0.252	76.8
N. W. Greening...	11	184	9093	2144.2	0.236	72.0
Average.....	12	222	7802	2156.8	0.276	84.1

RESULTS AND GENERAL OBSERVATIONS

A preliminary survey of the transpiration rate of many varieties, using only three shoots per variety, showed that Baldwin and Starking transpired at a high rate, while Arkansas Black and Northwestern Greening transpired at a low rate. When these varieties were later compared, using larger numbers of shoots, the same relationship held in two separate experiments. A summary of these experiments is shown in Table I. The data are largely self-explanatory. The relative ranking based on the transpiration rate of Starking at 100 is given. For the sake of brevity, a detailed account of atmospheric conditions is not given. The temperature averaged 78 degrees F., the relative humidity 58.8 per cent, and the atmometers transpired approximately 30 cc of water per day.

The transpiration rates of Grimes, Jonathan, Ortley, and Gravenstein were likewise compared in two experiments. A summary of these is shown in Table II. It will be noted that Grimes and Jonathan transpired at a higher rate than Ortley and Gravenstein. The Grimes variety seems to be unsatisfactory under drought conditions as it ceases shoot growth during a dry period. Table II also shows that Grimes and Jonathan each transpire about 9 per cent of their water at night, while Ortley and Gravenstein transpire only approximately 6 per cent each during that time. This may indicate a difference in stomatal control. While only the summary of the pair of experiments comparing these varieties is given, additional data show that the Grimes variety apparently transpires in accordance with the evaporating power of the air, while Ortley and Gravenstein cut down their rate of transpiration during periods favoring a high rate of

evaporation. A statistical study of the rate of transpiration of each shoot showed that the variation within the variety was small, and that differences in the transpiration rate of varieties were significant.

TABLE II—SUMMARY OF SECOND TRANSPIRATION STUDY OF FOUR APPLE VARIETIES

Variety	Number Shoots	Total Number Leaves	Total Leaf Area (Sq. Cm.)	Total Water Used			Rate per Sq. Cm. 1-24 hr. Hour (Cc.)	Relative Ranking (Per cent)
				Day (Cc.)	Night (Cc.)	Total (Cc.)		
Grimes.	14	266	7,460	1,512.4	157.1	1,669.5	0.244± .007	100.0
Jona- than	18	391	11,485	2,127.3	211.0	2,338.3	0.203± .004	90.6
Ortley	19	435	12,640	2,183.4	131.4	2,314.8	0.181± .010	80.8
Grav- enstein	18	351	13,648	2,188.1	140.4	2,328.5	0.170± .003	76.0

The transpiration rates of King, Wealthy, Delicious, and Red Canada were compared in duplicate experiments conducted on July 10 and September 9, respectively. A summary of these (Table III) shows that King and Wealthy transpired at a high rate, while Delicious and Red Canada transpired at a low rate. The relative ranking shows that there is widespread difference in the transpiration rates of King and Red Canada.

TABLE III—SUMMARY OF THIRD TRANSPIRATION STUDY OF APPLE VARIETIES

Variety	Total Number Shoots	Total Number Leaves	Total Leaf Area (Sq. Cm.)	Total Water Used 1-24 Hours (Cc.)	Rate of Transpiration per Sq. Cm. 1-24 hr. (Cc.)	Relative Ranking (Per cent)
King.....	13	266	8,544	2305.0	0.270	100.0
Wealthy.....	19	307	10,184	2504.9	0.246	91.2
Delicious.....	20	410	10,604	2082.1	0.196	72.8
Red Canada.....	16	280	10,167	1501.8	0.148	54.8

A few simple tests in which leaves of many varieties were weighed at frequent intervals while they were drying on laboratory tables indicated striking differences in the rate at which they lost water. Varieties which lost water rapidly upon drying also transpired at a high rate in the potometer studies. The rate of water loss decreased as drying proceeded. The percentage of water in the leaves decreased as the summer advanced.

DISCUSSION

The data gathered in this study show that apple varieties have a transpiration rate that is definite and distinct for each variety. Shoots of the same variety show but a small variation, with significant differences between varieties. Varieties in one table cannot be compared

with those in another table because of uncontrolled atmospheric conditions. Although one should not conclude that transpiration rates obtained in the potometers are representative of transpiration rates in the field and can be correlated with drought resistance, it is interesting to note that some varieties which were found to have a relatively high rate of transpiration are those which do not stand the hot, dry period usually found in late summer. These varieties also show a tendency toward the development of the physiological disorders known as water deficiency diseases. It seems likely that the rate of transpiration of varieties of apples under conditions causing a tension in the plant between the water loss and the water intake, may be important in affecting varietal susceptibility of the fruit to these physiological disorders.

Careful measurement of the cross section of 420 terminal leaves of 14 varieties showed no difference in leaf structure between the varieties transpiring at a high and at a low rate. The average thickness of all varieties was slightly over $\frac{1}{4}$ millimeter.

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Standard Rainfall

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A NEED is apparent to all students of crop production for more adequate descriptions of the climatic factors, especially when large areas are studied. The climatological data assembled by the U. S. Weather Bureau and other agencies need to be converted into measures applicable to crops growing under a wide range of conditions.

TABLE I—STANDARD RAINFALL CORRESPONDING TO MEAN MONTHLY TEMPERATURES

Mean Monthly Temperature	Standard Rainfall (Inches)	Mean Monthly Temperature	Standard Rainfall (Inches)	Mean Monthly Temperature	Standard Rainfall (Inches)
5	0.26	32	0.74	59	2.08
6	0.27	33	0.76	60	2.16
7	0.28	34	0.79	61	2.24
8	0.29	35	0.82	62	2.33
9	0.30	36	0.85	63	2.44
10	0.32	37	0.89	64	2.52
11	0.33	38	0.93	65	2.62
12	0.34	39	0.96	66	2.77
13	0.35	40	1.00	67	2.83
14	0.37	41	1.04	68	2.94
15	0.38	42	1.08	69	3.06
16	0.40	43	1.12	70	3.18
17	0.41	44	1.16	71	3.30
18	0.43	45	1.21	72	3.43
19	0.45	46	1.26	73	3.56
20	0.46	47	1.31	74	3.70
21	0.48	48	1.36	75	3.85
22	0.50	49	1.41	76	4.00
23	0.52	50	1.47	77	4.16
24	0.54	51	1.53	78	4.32
25	0.56	52	1.59	79	4.49
26	0.58	53	1.65	80	4.67
27	0.61	54	1.71	81	4.85
28	0.63	55	1.78	82	5.04
29	0.66	56	1.85	83	5.24
30	0.68	57	1.92	84	5.44
31	0.71	58	2.00	85	5.66

Such a measure for rainfall is proposed in "standard rainfall", which represents that amount necessary for good yields of crops on well drained fertile mineral soils of average water retaining capacity. With such a measure the monthly, semi-monthly, and annual rainfall could be expressed in times standard which is equivalent to adequacy, instead of the present absolute measures, inches and millimeters.

Similar measures of adequacy of annual rainfall have been developed by plant physiologists, soil scientists, and are being developed by geographers. Review of, and citations to, the literature have been made by Jenny (1) and Russell (2). None of the measures proposed

are adequate for periods shorter than a year, but there is a possibility of their being adapted for this purpose. Even when adapted they could not be used when only temperature and precipitation data are available, because they depend on evaporation and humidity data.

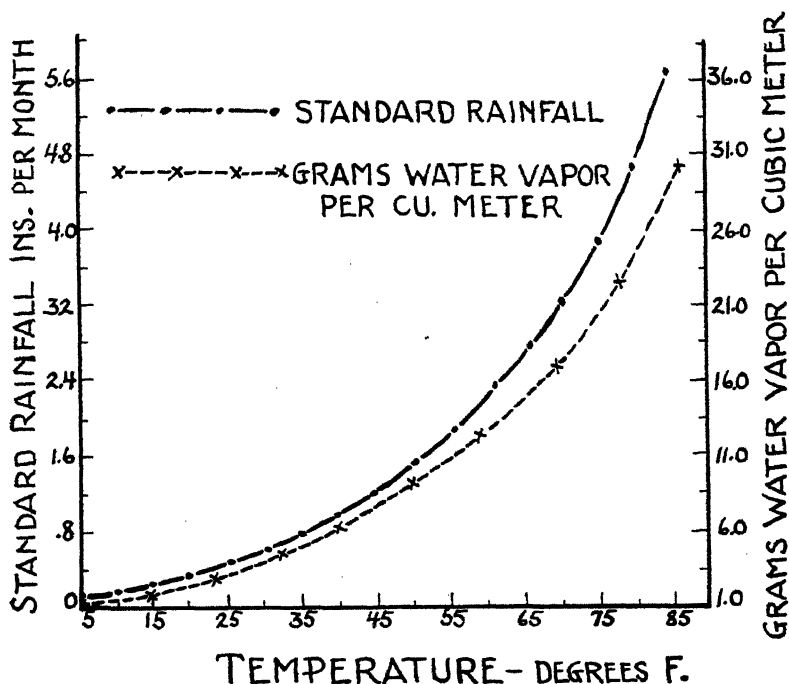


FIG. 1. Comparison of standard rainfall and water-holding capacity of the air.

A simple plan has been used in approximating standard rainfall from mean monthly temperatures, starting from 1 inch per month at 40 degrees F. mean temperature, and increasing the rainfall with temperature according to the Van't Hoff principle of increasing speed of chemical reactions, represented by $2^{\frac{x-40}{18}}$ when x is the mean monthly temperature in degrees F.

Table I gives the standard rainfall corresponding to mean monthly temperatures from 5 degrees to 85 degrees F.

The standard rainfall increases geometrically as the temperature increases arithmetically. This same relationship is found between the water holding capacity of air (space) and temperature (3). The similarity between the two is shown in Fig. 1 where the two curves are compared. Standard rainfall increases somewhat faster than the water holding capacity of air. Due to evaporation occurring mainly

TABLE II.—RAINFALL ADEQUACY ANALYSIS FOR ATHENS, GA.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean temperature (4).....	42.5	44.4	53.2	60.8	70.0	76.7	79.0	78.0	72.7	62.0	5.15	43.6	—
Mean rainfall (4).....	4.86	5.13	5.15	3.50	3.52	4.37	5.08	4.98	3.39	2.91	2.84	4.36	50.09
Standard rainfall.....	1.10	1.18	1.66	2.22	3.18	4.10	4.49	4.32	3.52	2.33	1.55	1.14	30.79
Ratio mean rainfall to standard rainfall...	4.42	4.35	3.10	1.58	1.11	1.06	1.13	1.15	0.98	1.25	1.83	3.82	1.63

during the daylight periods when the temperature is above the mean, the steeper curve of standard rainfall is justified.

It has not seemed possible to some that a measure of adequacy of rainfall would apply to both humid and arid regions. The mean monthly temperatures of the growing season are 10 to 20 degrees

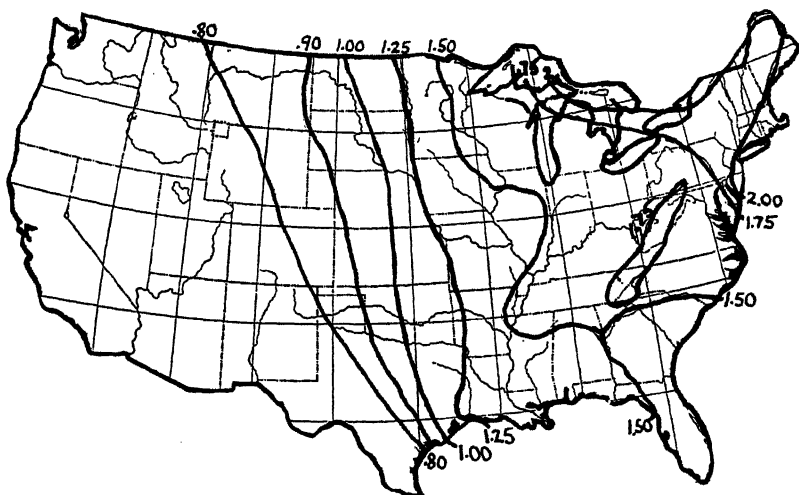


FIG. 2. Regions of annual moisture adequacy of the United States east of the Rocky Mountains.

higher in arid than in humid regions of the latitude and altitude. These higher temperatures increase the standard rainfall approximately 50 to 100 per cent which corresponds very well to the estimates for increased need of water in dry regions. Fig. 2 shows the division of the U. S. east of the Rocky Mountains into regions of varying annual moisture adequacy. The values given are secured by dividing the mean annual rainfall by the summation of the standard rainfall for the 12 months. The line 1.0 is where the mean annual rainfall is barely adequate for good yields on fertile, drained soils. It should correspond to the division line between humid and arid regions.

The rainfall adequacy of any station with mean temperature and rainfall values can be quickly calculated, as Table III for Athens, Ga., will indicate.

This ratio of mean rainfall to standard rainfall, for Athens indicates there is a great excess of moisture in December, January, February, and March, a moderate excess in April and November, a slight excess in midsummer, and a deficiency in September. The actual conditions at Athens are very much like the above description when the mean monthly rainfall and temperatures are approximately normal. Similar analyses from Florida to North Dakota and from the New England states to California indicate correctly the dry and wet

portions of the year, corresponding to the published descriptions of conditions so far as the writer has been able to determine.

After the root zone of a soil is wet, a crop will develop normally for a certain time without further additions of water, but after a while injurious results of drought appear. The name "drought period" is suggested for the time normal growth continues. The length of a drought can be measured in drought periods instead of days without rain. A good approximation of such a measure for well drained soils of moderate richness is found in the ratio between readily available water for crops in the root zone of a soil and standard rainfall. Hill soils about Athens, Ga., have a reservoir capacity of approximately 2 inches of water readily available to annual crops. The standard rainfall in January for Athens is 1.10 inches and for July, 4.49 inches. The ratios of water-holding capacity to standard rainfall for January and July are 1.8 and .45 respectively. The drought period of one during winter at Athens is 1.8 months and of one during summer .45 month. General observations indicate a 2-month rainless period in mid-winter at Athens is not more injurious than a 2-week rainless period in mid-summer. A rainless period of $3\frac{1}{2}$ months in winter at Athens would normally be a drought of two periods duration, while one of $3\frac{1}{2}$ months in mid-summer would be of about seven periods of duration.

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Effect of Fruit Thinning Upon Carbohydrate Accumulation, Formation of Fruit Buds and Set of Bloom in Apple Trees

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FRUIT thinning of apples has become established as a commercial practice for essentially three reasons: (1) more economical removal of blemished fruit at thinning time than in the packing house at harvest time, (2) better size of fruit on thinned than on unthinned trees, and (3) increase in the efficacy of spraying against codling moth when no apples are left touching one another. There is little evidence, however, to show to what extent the vigor of the trees and regularity of production can be increased by thinning. The works of Haller and Magness (1,2), Magness (3), and Magness and Overley (4) with varying numbers of leaves per fruit on ringed branches have shown that with an increased number of leaves per apple there was increased size of fruit, increased sugar content of fruit, and increased fruit bud formation. Such results show that the developing fruits make large demands upon the tree for food, and that the leaves are of utmost importance in the production of this food.

If thinning the fruit from ringed branches to increase the number of leaves per fruit resulted in sufficient food available for increased development of the fruit and buds, then a sufficiently early and heavy thinning of entire, normal trees should insure available food for increased development of the whole tree. Increased development should mean more growth, more fruit buds formed each year, a larger set of bloom, and increased spur and leaf development while the tree is producing a commercial crop. To observe the effect of thinning upon such features of tree response, thinning experiments were started in orchards in the Shenandoah-Cumberland region during the late spring and summer of 1930.

OUTLINE OF METHODS

Oldenburg, Rome Beauty, York Imperial, and Delicious trees were carefully thinned to leave approximately the desired numbers of leaves per fruit. The approximate number of leaves per fruit on adjacent unthinned (check) trees was also determined. From 3 to 8 weeks after the thinning, spur or shoot samples from thinned and unthinned trees were preserved in 80 per cent alcohol and later analyzed for reducing sugars, total sugars, and starch.

The Oldenburg trees had a very heavy bloom in the spring of 1930, and although a late freeze killed 40 to 60 per cent of the bloom, the uninjured bloom set a very heavy crop. All trees had been receiving

10 pounds of nitrate of soda annually. Part of the trees were in an irrigation experiment, and the remainder were in adjacent non-irrigated blocks.

The Rome Beauty trees were also vigorous, and had likewise been receiving 10 pounds of nitrate of soda annually. These trees were carrying a heavy crop in 1930. Half of the trees used in these experiments were in irrigated blocks, and half were in non-irrigated blocks.

One block of large York Imperial trees in the King orchard had received little or no nitrogen fertilizer for many years, the soil was low in organic matter, and the trees were very low in vigor. A second block of trees of similar size in the Miller orchard, which had received 5 to 6 pounds of nitrate of soda annually and had cover crops turned under during 4 out of 5 years, was moderately vigorous. The trees in both orchards had received very little pruning.

A third block of York Imperial trees in Tonoloway orchard was carrying a moderately heavy commercial crop. The trees termed "very vigorous" had been receiving 15 pounds of nitrate of soda annually, and the trees termed "moderately vigorous" were in an adjacent non-nitrated row. Apparently sufficient roots of these non-nitrated trees had entered the adjacent nitrated soil to maintain the trees in moderate vigor. These two groups of trees had been receiving a heavy detailed pruning each winter.

The Delicious trees were small and moderately vigorous, had been receiving about 5 pounds of nitrate of soda annually, and had been pruned very little during the life of the trees. These trees had been bearing biennially and had a heavy crop in 1930.

The per cent of growing points blossoming in 1931 was determined and was used as a measure of fruit bud formation. The per cent of bloom setting fruit was also determined. Since set usually decreased as the amount of bloom increased, such figures did not show whether the set, in proportion to the amount of bloom, was increased by the thinning; so the product of per cent bloom and per cent set, called per cent of growing point having fruit, was calculated. If this product was greater for the thinned than for a check tree, the set on the thinned tree was considered greater than on the check tree.

RESULTS SECURED

This brief report will not permit a presentation of the data obtained, so that only a summary of the results of each experiment will be given.

Oldenburg—Two non-irrigated Oldenburg trees were thinned on May 11, two weeks after full bloom. One tree was thinned to leave about 50 leaves and the other to leave about 100 leaves per fruit. The thinning greatly increased the size of the spurs, the leaf area per spur, the formation of fruit buds, and the set of bloom, as compared with two check trees. Although the thinning did not result in material increases in per cent of carbohydrates, the absolute amounts per

spur was greatly increased as compared with the checks. The total yield for 1930 and 1931 for the thinned trees was greater than for one check tree and slightly less than for the other check tree.

Two vigorous, non-irrigated Oldenburg trees were thinned on June 3, removing 86 to 90 per cent of the apples to leave 50 leaves per fruit. Two other trees with a lighter initial crop were thinned by removing 85 to 86 per cent of the apples to leave 100 leaves per fruit. Thinning in both cases resulted in increased green weight of the spurs, increased starch accumulation in the spurs, increased formation of fruit buds, and increased set of bloom the following spring, as compared to the checks. Considering relative size of the check and thinned trees the total yields for 1930 and 1931 for all four thinned trees would be fully as great as for the check trees. Increased yield for 1931 equalled the decrease for 1930.

In the case of the irrigated trees, thinning two trees on June 4 by removing 70 to 82 per cent of the apples to leave 50 leaves per fruit resulted in a smaller depletion of reducing sugars in the spurs, and in the case of one of the trees the thinning increased the formation of fruit buds and set of blossoms the following spring as compared with two check trees. This thinning of irrigated Oldenburg trees did not result in an increased green weight of spurs or increased starch accumulation as occurred when the non-irrigated trees were thinned. Thinning two trees on June 1 by removing 92 to 95 per cent of the apples to leave 100 leaves per apple resulted in increased leaf area per spur, less depletion of reducing sugars, increased fruit bud formation, and increased set of bloom the following spring, as compared with check trees. Thinning these irrigated trees caused a reduction of yield in 1930 as compared with the check trees and an increase in yield in 1931 of three out of four trees. One heavily and one moderately thinned irrigated tree showed a greater total yield for 1930 and 1931 than the check trees.

Rome Beauty—Non-irrigated Rome Beauty trees thinned to leave 25 leaves per fruit showed a response indicating an underground water supply from the irrigated block, and therefore these trees will not be considered. Two non-irrigated trees, which were thinned on June 16 by removing 76 per cent of the apples to leave 50 leaves per fruit, showed increased weight of the terminals and an increased accumulation of reducing sugars and sucrose, as compared with the check trees. The thinning of these two trees did not result in increased fruit bud formation, as compared with check trees, but did result in greatly increased set of bloom the following spring. Tree variability prevents conclusions as to the effect of thinning upon yields of non-irrigated trees.

In the case of the irrigated Rome Beauty trees, removing 40 to 48 per cent of the apples from two trees on June 18, to leave 25 leaves per fruit resulted in slightly more reducing sugars in the terminals, in increased fruit bud formation, and in increased set of bloom the following spring, as compared to irrigated check trees. Thinning

of 76 per cent of the apples from two other trees, on June 16 to leave 50 leaves per fruit, did not result in more reducing sugars, but did result in increased accumulation of starch, in increased fruit bud formation, and in increased set of bloom the following spring, as compared with the irrigated check trees. Thinning these irrigated trees to leave 25 leaves per fruit reduced the yield of fruit in 1930 under that of the check trees, and thinning to leave 100 leaves per fruit reduced the 1930 yield even more than did the lighter thinning. Although this thinning increased the 1931 yield, as compared with the check, the total yield for 1930 and 1931 was increased over the check in only one out of four trees.

York Imperial Trees Bearing a Heavy Crop—In the case of York Imperial trees in the King orchard, low in vigor and bearing a very heavy crop, none of the trees formed any fruit buds. Removing 87 per cent of the fruit on June 24 from one tree to leave 100 leaves per fruit did not result in the formation of any fruit buds. In the Miller orchard, where the moderately vigorous trees were bearing a very heavy crop, unthinned trees formed no fruit buds, and removing 78 per cent of the fruit on June 25, to leave 100 leaves per fruit on one tree also did not result in any fruit buds. Defruiting one moderately vigorous tree on June 25 increased the accumulation of starch, as compared with the check and the thinned trees, but even this rigorous treatment did not result in fruit bud formation. Thus thinning or defruiting on June 25 moderately vigorous York Imperial trees bearing a very heavy crop did not result in fruit bud formation.

Delicious—Unthinned, moderately vigorous Delicious trees formed few fruit buds. Thinning two trees on June 25 by removing 80 per cent of the fruit to leave 100 leaves per apple, did not significantly increase the formation of fruit buds but did result in greatly increased set of bloom the following spring, as compared with three check trees. Defruiting one tree on June 24 did not result in greater fruit bud formation than occurred in the check trees, but did cause greatly increased set of bloom. The thinned trees and the defruited tree showed a greater accumulation of sucrose and starch by July 12 than did the check trees.

York Imperial Trees Bearing a Moderate Commercial Crop.—In the Tonoloway orchard the very vigorous unthinned York Imperial trees, bearing a moderate commercial crop, formed more fruit buds than moderately vigorous unthinned trees. Thinning both moderately vigorous and very vigorous trees on June 30 to leave 50 leaves per fruit resulted in increased fruit bud formation and increased set of bloom the following spring, as compared to the check trees of corresponding vigor. The thinning of the very vigorous trees resulted in two to four times as much fruit bud formation as resulted from similar thinning of trees of only moderate vigor. Thinning two moderately vigorous trees on June 29 to leave 100 leaves per apple resulted in increased fruit bud formation and set of bloom of only one tree as compared to the check, but a similar thinning of two

very vigorous trees increased the formation of fruit buds and set of bloom of both trees as compared with the moderately vigorous trees receiving similar thinning, and also as compared with very vigorous trees receiving no thinning. The leaf area per spur on very vigorous trees thinned to leave 100 leaves per apple was increased over that of the very vigorous check trees. Thinning increased the total yields for 1930 and 1931 for all the very vigorous trees, and for three out of four of the moderately vigorous trees.

DISCUSSION

Although heavy thinning increased in all cases the size and color of the fruit, as compared to no thinning, this thinning also showed pronounced effects upon the vigor and productivity of the trees. Thinning non-irrigated Oldenburg and Rome Beauty trees before June 20 resulted in increased growth of the twigs as compared to no thinning. Comparable irrigated trees which made more growth than non-irrigated trees, did not show such responses to thinning. In some cases early thinning resulted in an increase in the size of the leaves, as compared with the check. In nearly all cases thinning increased the accumulation of certain carbohydrates as compared with the check.

In nearly all cases where trees blossomed the spring following the thinning, the thinned trees set more blossoms than the unthinned trees. In the case of the Oldenburg, Rome Beauty, and Delicious, the thinned trees that showed an increased set of bloom as compared with the check trees, also had shown an increased carbohydrate accumulation in three to eight weeks after thinning the previous summer.

The formation of fruit buds was increased by thinning, as compared with unthinned trees, in nine out of ten Oldenburg trees, in all irrigated Rome Beauty trees, and in seven out of eight vigorous York Imperial trees bearing a moderate crop. Thinning on June 25 of moderately vigorous Delicious trees, bearing a heavy crop did not result in increased fruit bud formation as compared with the check. Also, York Imperial trees either in low vigor or in moderate vigor, which were bearing a very heavy crop, formed no fruit buds at all, and heavy thinning on June 24 and 25 did not result in the formation of any fruit buds.

Moderately vigorous York Imperial trees, bearing only a moderate commercial crop, did form some fruit buds, but very vigorous trees showed much more fruit bud formation than the moderately vigorous trees. Thinning increased this fruit bud formation, the greater increase following thinning being in the very vigorous trees. The set of blossoms on the thinned, very vigorous trees was also greater than on the thinned moderately vigorous trees. Thus the response to thinning was greater in the more vigorous trees.

Data secured up to the present time, based on one year's complete work, indicate that fruit thinning of vigorous trees, if sufficiently

heavy to result in a surplus of synthesized products from the leaves, will usually result in increased fruit bud formation, even if the thinning is done as late as July 1. On non-vigorous trees, such increased fruit bud formation has not occurred. Thinning also greatly increased per cent set of bloom. A detailed report, including the second season's work, will be published elsewhere.

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Effect of Thinning Before the June Drop upon Fruit Production

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THAT the June drop of apples is related to nutritional conditions is well known, but the extent to which it can be reduced by experimental means has not been definitely reported. In addition the effect on size of fruit of thinning before rather than after the June drop has been given relatively little attention.

TABLE I—RELATION OF NUMBER OF FRUITS TO A CLUSTER TO ABSCISSION DURING THE JUNE DROP—YELLOW TRANSPARENT, 1930

At Thinning			After June Drop (June 18)					
No. Fruits Left per Cluster	No. Clusters	Percent Clusters with Fruits	Per cent Fruits Remaining	Per cent clusters Bearing				
				No Fruit	1 Fruit	2 Fruits	3 Fruits	4 Fruits
1 lateral...	312	93.6	93.6	6.4	93.6	—	—	—
2 laterals..	339	96.8	84.8	3.2	24.2	72.6	—	—
3 laterals..	367	94.8	70.0	5.2	18.2	40.6	36.0	—
4 laterals..	163	93.3	54.6	6.7	17.2	32.5	38.0	5.6

In 1930 over 1100 fruiting points on a large, vigorous 37-year-old Yellow Transparent tree were selected at random and tagged when the fruits were slightly over $\frac{1}{2}$ inch in diameter (May 13). The fruits were similar in size and three or four fruits had set on each cluster base. The fruiting points were partially defruited leaving one to four lateral fruits on each. Immediately after the June drop (June 18) the number of fruits on each selected cluster base was noted (Table I).

Ninety-four per cent of the cluster bases which were thinned before the June drop so as to leave but one fruit held this single fruit until harvest. With each progressive increase in the number of fruits left to a cluster base, the percentage of fruits remaining after the June drop decreased proportionately. For example, with four fruits left to a cluster, the percentage set was 55.

These data were similar to those obtained with Grimes Golden and Ensee from 1926 to 1928 in connection with other fruit setting studies. When clusters of these varieties were thinned before the June drop to one fruit to a cluster, 90 or more per cent of the fruits remained.

In 1931 representative trees of Oldenburg, Wealthy, and Red June were thinned before the June drop. Two adjacent 38-year-old Oldenburg trees (133 and 132) were thinned, one before and one after the June drop. Oldenburg trees 400 and 228 and the Wealthy tree were thinned like Oldenburg 133 leaving one or two branches unthinned until after the June drop. On the tree thinned before the June drop

(133) two branches were not thinned until after this drop. Two adjacent 30-year old trees of Red June of the same vigor were treated like Oldenburg 133 and 132, one being thinned before the June drop and one after. In all cases one fruit was left to a cluster and the fruiting points were spaced, as far as possible, to not less than 6 inches apart.

TABLE II—EFFECT OF THINNING BEFORE THE JUNE DROP UPON ABSCISSION—OLDENBURG, RED JUNE, WEALTHY, 1931

	Per cent Fruits After June Drop						
	Oldenburg				Red June		Wealthy
	133 Thinned Before	132 Unthinned	400 Thinned Before	228 Thinned Before	499 Thinned Before	500 Unthinned	290 Thinned Before
Thinned portion							
Fruits at random	99.2	—	92.9	97.0	98.6	—	98.6
Branch 1	99.2	—	87.6	88.3	—	—	92.5
Branch 2	96.0	—	86.6	—	—	—	95.1
Unthinned portion							
Fruits measured	34.0	51.8	48.3	42.0	62.9	72.9	33.8
Branch 1	47.9	42.6	21.5	16.1	29.1	34.9	14.7
Branch 2	25.1	22.6	—	—	32.4	38.5	—
Per cent of Clusters Bearing 0-4 Fruits After June Drop							
Unthinned portion							
Branch 1							
0 fruits	8.2	25.7	—	55.6	31.0	29.3	—
1 fruit	23.5	17.4	—	27.2	39.8	45.0	—
2 fruits	35.0	25.6	—	13.8	20.1	21.5	—
3 fruits	23.5	23.2	—	2.4	6.7	3.8	—
4 fruits	9.8	8.1	—	1.0	2.4	0.4	—
Branch 2							
0 fruits	43.5	41.7	55.8	—	39.0	28.3	—
1 fruit	32.6	38.0	30.5	—	41.5	47.1	—
2 fruits	12.9	17.4	11.4	—	10.5	19.3	—
3 fruits	9.1	2.9	1.8	—	3.0	3.4	—
4 fruits	1.9	0.0	0.5	—	0.0	0.9	—

In Table II is given the percentage of fruit which remained through the June drop on the thinned and unthinned branches and trees. On Oldenburg 87 to 99 per cent of the thinned fruits remained through the June drop, while on the unthinned portions only 16 to 52 per cent of the fruits survived this abscission period. On Wealthy 92 to 99 per cent of the fruits left after thinning remained on the tree at maturity while only 14 to 34 per cent of the fruits on the unthinned branches held throughout the June drop. On the Red June tree thinned early 99 per cent of the fruits remained at harvest while on the unthinned tree only 29 to 73 per cent of the fruits remained after the June drop.

It is evident that thinning before the June drop, by removing the competition between the adjacent fruits on the cluster base, largely eliminated the June drop. The very small abscission of the fruits

TABLE III—INCREASES IN WEIGHT OF APPLES THINNED BEFORE, RELATIVE TO THOSE THINNED AFTER, THE JUNE DROP, 1931

Variety and Treatment	Circumference of Fruit (Cm.)			Gain on June 24 (Cm.)	Gain on Sept. 3 Over June 24 (Cm.)	Total Gain (Cm.)
	May 26	June 24	Sept. 3			
Oldenburg—133						
	2.8±.022	14.2±.072	21.0±.138	11.4±.075	6.8±.155	18.2±.140
	2.7±.023	12.4±.083	20.9±.119	9.7±.086	8.5±.145	18.2±.121
				1.7±.133	1.7±.212	0.0
Oldenburg—132						
	3.0±.018	11.8±.055	19.7±.267	8.8±.058	7.9±.272	16.7±.267
Oldenburg—400						
	3.6±.036	13.2±.074	20.0±.109	9.6±.082	6.8±.132	16.4±.115
	3.3±.054	11.8±.086	18.5±.151	8.5±.101	6.7±.174	15.2±.160
				1.1±.130	0.1±.21	1.2±.198
Oldenburg—228						
	2.5±.028	13.9±.077	20.3±.132	11.4±.082	6.4±.152	17.8±.135
	2.5±.031	12.5±.081	19.7±.150	10.0±.087	7.2±.170	17.2±.153
				1.4±.119	0.8±.228	0.9±.204
Red June—499						
	2.8±.028	10.3±.059	16.3±.104	7.5±.065	6.0±.119	13.5±.108
	2.8±.023	9.0±.072	15.0±.099	6.2±.077	6.0±.122	12.2±.102
				1.3±.101	0.0	1.3±.148
Red June—500						
	3.0±.030	9.5±.069	16.2±.105	6.5±.075	6.7±.125	13.2±.109
Wealthy—280						
	2.4±.023	11.8±.058	20.9±.062	9.4±.062	9.1±.085	18.5±.066
	2.3±.030	10.5±.100	20.8±.179	8.2±.104	10.3±.209	18.5±.181
				1.2±.121	1.2±.226	0.0

TABLE IV—RELATION BETWEEN SIZE AND DATE OF HARVEST OF FRUIT FROM TREES THINNED BEFORE AND AFTER THE JUNE DROP, 1931

Picking Date	Percentage of Fruit Graded to Size						Total Crop (Pounds)		Per cent Crop Picked	
	Above 2½ Inches		Between 2¼-2½ Inches		Below 2¼ Inches		Thinned Early	Thinned Late	Thinned Early	Thinned Late
	Thinned Early	Thinned Late	Thinned Early	Thinned Late	Thinned Early	Thinned Late				
Red June Tree 499 (thinned early) and 500 (thinned late)										
Aug. 6.....	17.2	0.3	59.5	46.6	23.3	53.1	163	168	14.8	21.0
Aug. 10.....	11.7	0.6	59.6	47.0	28.7	52.4	384	336	34.9	42.0
Aug. 13.....	11.4	0.5	59.7	45.8	28.9	53.7	370	192	33.6	24.0
Aug. 18.....	6.0	—	52.6	34.7	41.4	65.3	133	75	12.1	9.4
Aug. 22.....	7.8	—	51.0	35.1	41.2	64.9	51	28	4.6	3.6
Total.....	11.5	0.4	58.4	45.1	30.1	54.5	1101	799	100	100
Oldenburg Tree 133 (thinned early) and 132 (thinned late)										
Aug. 7.....	70.1	36.5	28.7	61.4	1.2	2.1	164	96	15.3	11.1
Aug. 14.....	86.7	59.3	12.9	39.3	0.4	1.4	272	354	25.3	41.0
Aug. 18.....	80.8	54.8	18.2	40.7	1.0	4.5	198	155	18.4	18.0
Aug. 22.....	70.2	81.7	28.2	16.2	1.6	2.1	188	142	17.5	16.5
Aug. 27.....	78.8	58.3	19.8	39.3	1.4	2.4	212	84	19.7	9.7
Sept. 3.....	29.3	12.5	46.3	43.8	24.4	43.7	41	32	3.8	3.7
Total.....	76.5	57.8	21.6	38.4	1.9	3.8	1075	863	100	100

on the thinned branches indicated the predominant importance of competition for food and water as the factor influencing the severity of the June drop.

Table III presents the comparative circumferences on June 24 and September 3 of the apples on the branches and trees thinned before and after the June drop. In all cases on June 24 the fruits on the portions left unthinned had not increased in size as much as the fruits on the thinned branches and trees. Statistically the differences were decidedly significant. The thinned fruits were from 1.1 to 1.7 cm. greater in circumference, a range which represented a 25 to 50 per cent greater increase in volume through the June drop period.

On one Oldenburg tree and on the Wealthy tree the fruits on the portions left unthinned until after the June drop caught up with the fruits on the early thinned branches by harvest. On the remaining Oldenburg trees, however, and on Red June tree 499, the fruits on the portions thinned early were still decidedly larger at harvest than those on the branches thinned late. These data suggest that the use of unthinned branches on trees, the greater portions of which are thinned, may be subject to considerable error since there was evidence that the fruits on an unthinned branch tend to be influenced by the adjacent thinned branches. It is more by comparison of the fruits on the early thinned trees with those on the late thinned trees that the difference in size due to early thinning is clearly evident at harvest. These data are given in Table IV.

In this table, data are presented concerning the size of fruit at the various pickings of paired Oldenburg and Red June trees, one of which was thinned early and one late. In both varieties a greater proportion of the fruit at the early pickings on the trees thinned early was large. On the Red June tree thinned late only 0.4 per cent of the total weight of the fruit was above $2\frac{3}{4}$ inches diameter, while 11 per cent was over this size on the tree thinned before the June drop. Furthermore, in Red June, which is normally a small-fruited variety, only 30 per cent of the total crop on the tree thinned early was $2\frac{3}{4}$ inches diameter while more than half on the tree thinned just after the June drop was under this size. Palmer (1) reported data in the annual report of the Summerland Station indicating that in Oldenburg and Yellow Transparent fruits on trees thinned before the June drop were of greater size at harvest than those on trees thinned after all dropping had ceased.

It is also to be noted that there was a much greater total crop in pounds on the trees thinned early than on those thinned late. This may be due to the fact that a more even distribution of fruiting points could be made in the early than in the late thinning.

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Results of Some Experiments in Pruning Young Apple Trees

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THE present investigation was undertaken to determine some of the effects upon young apple trees when given the following treatments, namely, no pruning, light pruning, and heavy pruning. The pruning studies began at the time of planting, April 15, 1923.

One lot of 21 trees was unpruned but otherwise was given the same treatment as the other trees. Another lot, consisting of 16 trees, was pruned at planting time to the modified leader system. A third lot of 13 trees was pruned to the open center system. The two types of pruning and training, were continued each year to 1930, inclusive.

The trees were planted in rows 24 feet apart and 15 feet apart in the row. For comparison, 2 trees of each variety were planted together in most cases, and each received different treatments as regards pruning, namely, either no pruning, pruning to modified leader system, or pruning to open center system. Each year the pruning was done during late winter or early spring. When the final data was taken, December 1931, the trees represented typical specimens of the three treatments used.

As is well known, the open center system of pruning required rather heavy cutting. The modified leader type required considerably less pruning back of the central leader. The only pruning treatment which the unpruned trees received consisted of the removal of suckers from the base of the tree trunks.

During the nine seasons of growth, 1923 to 1931 inclusive, the spaces between the tree rows were cultivated. Until the last two years the orchard was inter-cropped with truck crops and vegetables, like cabbage, tomatoes, beans, melons, potatoes, and the like. In 1930 and 1931 two of the spaces between the rows were set to strawberries. None of the trees were fertilized during the investigation. From one or two, to four or five spring and summer sprays have been applied each year. Dormant sprays have been made when necessary to keep San Jose scale under control.

As the trees are just coming into profitable bearing no accurate record has been kept as to the amount of fruit produced from the trees subjected to the different types of pruning treatment. It has been evident, however, that the trees with no treatment have, in general, come into bearing somewhat earlier and have produced more fruit. This was particularly true in 1931, when the largest crop was harvested.

The unpruned trees, having greater height and spread, may be readily distinguished. Moreover, it is easy to locate the trees pruned

TABLE I. GROWTH MADE BY PRUNED AND UNPRUNED TREES FROM TIME OF PLANTING 1923-31

Variety	No Pruning				Modified Leader				Open Center			
	Height		Spread		Height	Spread		Circ.	Height	Spread		Circ.
	Ft.	Ins.	Ft.	Ins.		Ft.	Ins.			Ft.	Ins.	
Jeffrey Red.	14	11	13	6	18	—	—	—	—	—	—	—
Jeffrey Red.	16	10	13	8	18.5	—	—	—	—	—	—	—
Duchess.	15	3	13	11	18	11	7	11	—	—	—	—
Rome.	17	7	19	—	19.5	14	3	15	—	—	—	—
Senator Crab.	—	—	—	—	—	17	10	17.5	5	16	—	16.5
Elysop Crab.	—	—	—	—	—	—	—	—	—	—	—	—
Maiden Blush.	17	5	21	9	24	—	—	—	—	—	—	—
Golden Delicious.	17	5	18	—	22	—	—	—	—	—	—	—
Golden Delicious.	18	—	18	—	21	—	—	—	—	—	—	—
Mother.	18	10	20	—	24	—	—	—	—	—	—	—
N. Y. Greening.	—	—	—	—	—	15	2	14.5	—	—	—	—
Liveland Raspberry.	—	—	—	—	—	16	2	15	2	13	—	—
Grimes.	17	7	22	—	19	—	—	15	13	3	—	15
Wealthy.	16	—	20	9	23	—	—	—	14	3	—	18
Golden Winesap.	—	—	—	—	—	16	9	—	16	20	6	21
Wealthy.	16	2	14	8	16	—	—	21	—	—	—	—
Fameuse.	—	—	—	—	—	—	—	—	16	17	8	20
York.	17	4	18	4	21	17	2	18	—	—	—	—
King David.	18	6	23	3	22	18	11	19	—	—	—	—
Jonathan.	—	—	—	—	—	—	—	—	—	—	—	—
Florence Crab.	—	—	—	—	—	15	2	13	9	9	10	12.5
Northern Spy.	15	2	11	8	14	14	3	15	13	14	1	15
Sweet Bough.	17	11	15	7	21	—	—	—	13	8	4	20
McIntosh.	12	2	19	10	20	—	—	—	13	8	—	—
Winesap.	—	—	—	—	—	13	10	19	12	19	10	19.5
Minkler.	15	5	22	2	24.5	—	—	—	—	—	—	—
Red Astrachan.	19	5	18	—	26	—	—	—	—	—	—	—
Collins Red.	—	—	—	—	—	18	2	—	12	10	11	12.5
Black Ben.	18	8	19	2	24	16	6	21	13	12	6	19
Ben Davis.	18	8	20	2	24	14	4	18	—	—	—	—
Ben Davis.	18	2	20	8	24	—	—	—	—	—	—	—
Yellow Newtown.	—	—	—	—	—	14	8	19	—	—	—	—
Spitzenberg.	—	—	—	—	—	13	10	18	13	9	—	17
Total.	348	113	376	97	439	238	82	256	169	180	75	220
	or	357.4 ft.	or	384.0 ft.	ins.	or	244.8 ft.	or	or	or	189.2 ft.	220 ins.

to the modified leader system, as they are intermediate in height and spread between the unpruned and open center trees.

Close examination of the unpruned trees shows that the branches are so thick that already some fruit spurs and small limbs are dying due to lack of sunlight. Moreover, the fruit produced in 1931 in the center of the unpruned trees was very poorly colored. It is true, also, that future fruit on these trees is likely to be borne largely on the periphery.

TABLE II—SUMMARY OF GROWTH MADE BY PRUNED AND UNPRUNED TREES, 1923-1931

Treatment	Ave. Height (Feet)	Ave. Spread (Feet)	Ave. Trunk Circum. (Inches)
No pruning.....	17.0	18.3	20.9
Modified leader.....	15.3	16.3	17.2
Open center.....	13.5	14.3	16.9

DISCUSSION

A study of the data presented, covering nine growing seasons, shows that the heaviest type of pruning, (open center) had the greatest dwarfing effect on growth as measured by height and spread of tree tops and circumference of trunks. Pruning less heavily (the modified leader system), produced a marked increase in growth as measured by the same standards. Unpruned trees made substantially stronger growth than the trees pruned to the open center or modified leader system.

Results quite similar to those given in this paper have been reported from California (7), New York (3), West Virginia (1), and Indiana (4). In England, Pickering (2) has reported findings comparable to these. Both Indiana (4) and Oregon (6) have published investigations dealing with pruning, and the results obtained agree, in general, with the findings reported in this paper.

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Tabular Biometrical Presentation of Pruning Treatments with Apple Trees

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FOR the purpose of studying the effects of different pruning treatments upon York Imperial and Stayman apple trees, an experimental plat was set out by the Horticulture Department of the Virginia Agricultural Experiment Station in the spring of 1915 near Blacksburg, Virginia. Respective plat series for the following treatments were maintained:

TABLE I—GROWTH AND YIELD RESPONSES OF APPLE TREES TO DIFFERENT PRUNING TREATMENTS

Comparison of Kinds of Pruning	Mean Trunk Growth Increase (inches)	In Favor of	Gain (inches)	Student Odds
York Imperial				
High-head.....	1.5	Low-head	.5	Infinite
Low-head.....	2.0			
Heavy.....	1.7	Light	.1	Infinite
Light.....	1.8			
High-head.....	1.5	Non-pruned	.6	10 to 1
Non-pruned.....	2.1			
Heavy.....	1.7	Non-pruned	.4	8 to 1
Non-pruned.....	2.1			
Light.....	1.8	Light	.9	51 to 1
Non-pruned.....	.9			
Low-head.....	2.0	Low-head	.1	1 to 1
Non-pruned (1).....	1.9			
Low-head.....	2.0	Non-pruned	.1	3 to 1
Non-pruned (2).....	2.1			
Dormant.....	2.1	Dormant	.5	169 to 1
June 20.....	1.6			
Dormant.....	2.1	Dormant	.4	49 to 1
August 20.....	1.7			
Dormant.....	2.1	Dormant	.4	21 to 1
October 20.....	1.7			
Dormant.....	2.1	—	—	—
Non-pruned.....	2.1			
June 20.....	1.6	Non-pruned	.5	9 to 1
Non-pruned (1).....	2.1			

TABLE I—*Continued*

Comparison of Kinds of Pruning	Mean Trunk Growth Increase (inches)	In Favor of	Gain (inches)	Student Odds
York Imperial				
June 20.....	1.6			
Non-pruned (2).....	2.0	Non-pruned	.4	8 to 1
August 20.....	1.7			
Non-pruned.....	2.0	Non-pruned	.3	73 to 1
October 20.....	1.7			
Non-pruned.....	2.0	Non-pruned	.3	5 to 1
Stayman				
High-head.....	1.6			
Low-head.....	1.7	Low-head	.1	3 to 1
Heavy.....	1.9			
Light.....	1.4	Heavy	.5	111 to 1
High-head.....	1.6			
Non-pruned.....	1.6	—	—	—
Heavy.....	1.9			
Non-pruned.....	1.6	Heavy	.3	13 to 1
Light.....	1.4			
Non-pruned.....	1.6	Non-pruned	.2	16 to 1
Low-head.....	1.7			
Non-pruned.....	1.8	Non-pruned	.1	1 to 1
Dormant.....	2.0			
June 20.....	1.6	Dormant	.4	123 to 1
Dormant.....	2.0			
August 20.....	1.7	Dormant	.3	83 to 1
Dormant.....	2.0			
October 20.....	1.4	Dormant	.6	22 to 1
Dormant.....	2.0			
Non-pruned.....	1.9	Dormant	.1	3 to 1
June 20.....	1.6			
Non-pruned (1).....	1.9	Non-pruned	.3	17 to 1
June 20.....	1.6			
Non-pruned (2).....	1.7	Non-pruned	.1	207 to 1
August 20.....	1.7			
Non-pruned.....	1.7	—	—	—
October 20.....	1.4			
Non-pruned.....	1.7	Non-pruned	.3	1 to 1

TABLE I—*Continued*

York Imperial				
Comparison of Kinds of Pruning	Mean Yield Per Tree (Pounds)	In Favor of	Gain (Pounds)	Student Odds
High-head.....	173	Low-head	163	9 to 1
Low-head.....	236			
Heavy.....	141	Light	89	14 to 1
Light.....	230			
High-head.....	173	Non-pruned	161	3 to 1
Non-pruned.....	334			
Heavy.....	141	Non-pruned	193	294 to 1
Non-pruned.....	334			
Light.....	230	Light	94	6 to 1
Non-pruned.....	136			
Low-head.....	226	Non-pruned	150	19 to 1
Non-pruned.....	376			
Dormant.....	186	Dormant	48	5 to 1
June 20th.....	138			
Dormant.....	186	Dormant	20	7 to 1
August 20th.....	166			
Dormant.....	186	October 20th	30	2 to 1
October 20th.....	216			
Dormant.....	186	Non-pruned	37	5 to 1
Non-pruned.....	223			
June 20th.....	138	Non-pruned	85	55 to 1
Non-pruned (1).....	223			
June 20th.....	138	Non-pruned	182	164 to 1
Non-pruned (2).....	310			
August 20th.....	166	Non-pruned	144	108 to 1
Non-pruned.....	310			
October 20th.....	216	Non-pruned	94	11 to 1
Non-pruned.....	310			
Stayman				
High-head.....	203	Low-head	45	70 to 1
Low-head.....	253			
Heavy.....	192	Light	71	99 to 1
Light.....	263			
High.....	203	Non-pruned	93	43 to 1
Non-pruned.....	296			
Heavy.....	192	Non-pruned	104	74 to 1
Non-pruned.....	296			
Light.....	263	Light	33	9 to 1
Non-pruned.....	230			

TABLE I—*Continued*

Comparison of Kinds of Pruning	Mean Yield Per Tree (Pounds)	In Favor of	Gain (Pounds)	Student Odds
Stayman				
Low.....	358	Low-pruned	44	8 to 1
Non-pruned.....	314			
Dormant.....	295	Dormant	104	11 to 1
June 20th.....	191			
Dormant.....	295	Dormant	75	17 to 1
August 20th.....	220			
Dormant.....	295	Dormant	63	4 to 1
October 20th.....	232			
Dormant.....	295	Dormant	18	1 to 1
Non-pruned.....	277			
June 20th.....	191	Non-pruned	86	151 to 1
Non-pruned (1).....	277			
June 20th.....	191	Non-pruned	217	637 to 1
Non-pruned (2).....	408			
August 20th.....	230	Non-pruned	178	1285 to 1
Non-pruned.....	408			
October 20th.....	232	Non-pruned	176	203 to 1
Non-pruned.....	408			

(1) Low-head, (2) High-head, (3) Heavy, (4) Light, (5) Dormant, (6) Early spring, June 20th, (7) Early summer, August 20th, (8) Late fall, October 20th, and (9) No pruning (six plats), to serve as checks.

In the low-head plats the trees were allowed to develop scaffold branches from 15 to 20 inches from the ground and in the high-head plats not lower than 3 to 4 feet.

A relatively greater amount of growth was removed from the trees in the heavy pruned plats as compared to those in the light pruned. In the light pruned series, growth removal was generally confined to any tendency towards undesirable competition, various injuries and incorrect spacing. Both the heavy and the light pruned trees were pruned during the winter when the trees were in the dormant condition.

The trees in the dormant series were pruned during the open days of winter. Six sets of trees that will be referred to as non-pruned were left unpruned to serve as checks. These trees were permitted to develop at random.

Pruning in early spring or June 20th, early summer or August 20th and late fall or October 20th consisted in a general corrective removal approximately for these dates.

Annual trunk growth increases were recorded for the past 15 years and the yields for the past 8 years. The results of these data

subjected to a biometrical analysis are presented herewith, in tabular form.

Low-head pruning shows a gain of 160 pounds per tree of apples over high-head in York Imperial. Although this yield gain is favored by Student odds of only 9 to 1, it is supported by the half-inch gain in annual trunk increase, with the odds infinitely in favor of the latter. It may be considered not of significance¹ but it is given further weight in its favor when the favorable responses in Stayman for this treatment are also taken into consideration. In the latter variety there is a significant gain of 40 pounds of fruit in favor of the low-head treatment. For growth response in Stayman the 1.1-inch gain in favor of the low-head treatment is not significant. Just the same, a prevailing consistency for this treatment with the significant odds in its favor in at least two responses obviously establishes biological significance in favor of the low-head type of pruning. Judging from such results the chances are very much in favor of securing better growth responses and higher yields with low-head type of pruning under these same conditions.

Light pruning in York Imperial shows a gain of 89 pounds of fruit over heavy pruning. With odds of 14 to 1 this would not be considered a significant gain mathematically. However, the chances that this treatment would generally show higher yields under similar conditions over heavy pruning, are increased with the significant gain of 71 pounds of fruit in Stayman. Furthermore, the lightly pruned trees show these gains even with a topography favoring the heavily pruned plats.

No measurable differences had shown up between the low-head and the non-pruned treatments in either York Imperial or Stayman until the last three years of the experiment when the low-head treatment showed gradually increased responses in yields. This of course, is not brought out in the tables which cover the entire period of the experiment.

Non-pruning in York Imperial shows a significant gain of 193 pounds of fruit over heavy pruning and a significant gain of 104 in Stayman. This is particularly interesting in that the non-pruned trees are in a somewhat less favorable topography.

Light pruning treatments in both York Imperial and Stayman showed gains over the non-pruned trees. These gains are not mathematically significant but the chances that this treatment may show the higher responses under similar repetitions are increased because gains for this treatment show up in both varieties, along with significant gains in growth in York Imperial.

Although the dormant pruning series show consistent gains in yields and growth both for York Imperial and Stayman over the series pruned June 20th, August 20th, and October 20th, allowance must be made for the topography that slightly favored the dormant series.

¹Significance will be used in this discussion in its biometrical meaning.

There is a significant yield gain throughout for both York Imperial and Stayman favoring the non-pruned trees when compared with those pruned on June 20th, August 20th, and October 20th. The non-pruned trees very likely would have shown up still better if they had been in a topography as good as any of those with which they were just compared.

Judging from the results secured as presented herewith in tabular form, the chances are very good in an average Virginia apple orchard during the first 15 years to show yield gains as follows: (1) Low- over high-head; (2) light over heavy and (3) non-pruned over heavy, June 20th, August 20th, or October 20th. Considering these results from a practical standpoint, the higher yields are to be expected from the lower headed trees that are kept pruned with intelligent moderation during the dormant period.

A Comparison of Different Methods of Taking Samples of Apples in Experimental Plots

By M. J. DORSEY and R. L. McMUNN, *University of Illinois, Urbana, Ill.*

IN this study an attempt has been made to test the accuracy or reliability of some of the different methods of taking samples where it is desired to compare one treatment with another by determining the effect of each upon the size of fruit. The Jefferis trees under study were 29 years old and averaged about 30 feet in height and 25 feet in limb spread. The fruit on the different trees varied greatly in size, some trees producing a larger proportion of the smaller sizes than others, so that it may be said that the usual variations between trees in an orchard were present in this instance.

THE DIFFERENT SAMPLES TAKEN FOR COMPARISON

The 20-fruit sample: In taking this sample the crop on the tree was studied carefully and 20 fruits which seemed to give a proportional representation of the different sizes on the tree were selected from the lower branches around the tree, within reach from the ground. In other words, there was a conscious effort to fit the 20-fruit sample to the crop.

The 100-fruit sample: Next, a 100-fruit sample was selected in the same way as the 20-fruit sample.

The individual limb sample: In selecting the single limb sample, an attempt was made to find a limb on which the fruit ranged in size in about the same proportion as that on the remainder of the tree. It may have been located anywhere on the tree, the object being to select a typical limb rather than one from any particular location. All of the apples on the limb and those that dropped from it during picking were included in this sample.

The vertical section: In picking this lot a ladder was placed against the tree (on the north side, except with two) and the fruit picked as far as could be reached conveniently to the right and left (approximately 7 feet), from the top to bottom and in to the center. This sample was taken after the 20-fruit, the 100-fruit, and the individual limb lots had been picked and included all fruits knocked off or dropped by the pickers within the limits of the sample.

The 200-pound sample: This sample was taken after the fruit had been placed in the storage in capped and lidded bushel baskets. Five baskets of fruit were picked at random from the lots for each tree and enough fruit removed from one basket to adjust the weight to 200 pounds. The total weight given in Table I for this lot is below 200 pounds due to the variation in weight of some of the baskets. The fruit in this lot was picked, put in baskets, and placed in the storage by a different crew than that which selected the baskets for sizing.

TABLE I.—YIELD IN NUMBER AND WEIGHT OF FRUIT FOR THE DIFFERENT SIZES AND SAMPLES

Sample	Number of Fruits in the Different Sizes					Total	Weight of Fruit in the Different Sizes (Pounds)					Total
	0-1¾	1¾-2	2-2¼	2¼-2½	2½-up		0-1¾	1¾-2	2-2¼	2¼-2½	2½-up	
(Tree 7)												
20-fruit.....	2	2	8	7	1	20	0.2	0.3	1.6	1.6	0.3	4.0
100-fruit.....	7	9	41	37	5	99	0.6	1.6	6.1	8.0	1.3	17.6
Limb.....	16	20	100	52	0	188	1.1	2.1	12.9	9.7	0.0	25.8
Vertical.....	111	137	365	171	23	807	8.8	14.4	53.0	42.6	5.2	124.0
200-pound.....	201	145	621	335	57	1,359	14.9	14.5	90.2	64.9	14.1	198.6
Remainder.....	599	626	2,136	1,410	322	5,093	45.5	62.4	300.5	273.5	78.2	760.1
Drops.....	26	37	140	110	37	350	3.0	4.5	18.9	19.7	8.5	54.6
Total.....	962	976	3,411	2,122	445	7,916	74.1	99.8	483.2	420.0	107.6	1184.7
(Tree 9)												
20-fruit.....	1	3	12	4	0	20	0.1	0.3	1.7	0.7	0.0	2.8
100-fruit.....	11	20	59	10	0	100	0.7	2.0	8.6	1.6	0.0	12.9
Limb.....	51	52	110	32	0	245	3.2	5.1	15.7	5.7	0.0	29.7
Vertical.....	207	241	319	109	2	878	14.0	23.7	44.7	19.8	0.4	102.6
200-pound.....	253	331	718	220	19	1,541	16.4	32.7	99.5	41.0	4.3	193.9
Remainder.....	572	645	1,503	407	36	3,163	38.0	64.5	210.8	76.9	8.3	398.5
Drops.....	26	31	204	205	35	501	2.2	3.7	29.7	39.1	8.7	83.4
Total.....	1,121	1,323	2,925	987	92	6,448	74.6	132.0	410.7	184.8	21.7	823.8
(Tree 10)												
20-fruit.....	0	2	6	11	6	25	0.0	0.1	1.0	2.1	1.5	4.7
100-fruit.....	4	16	55	21	4	100	0.3	0.9	7.9	4.0	0.9	14.0
Limb.....	9	4	34	67	14	128	0.6	0.4	4.1	13.3	3.4	21.8
Vertical.....	191	313	363	94	0	961	12.7	23.0	51.9	17.9	0.0	105.5
200-pound.....	243	272	668	289	26	1,498	16.0	27.6	93.2	56.3	5.9	199.0
Remainder.....	551	583	1,364	559	117	3,174	38.2	59.4	190.0	105.4	28.7	421.7
Drops.....	91	60	206	201	39	597	6.0	6.3	31.0	39.0	9.2	91.5
Total.....	1,211	1,128	2,696	1,242	206	6,483	84.1	107.4	379.1	238.0	49.6	858.2

(Tree 16)	0	1	5	4	13	23	0.0	0.2	0.8	0.9	4.2	6.1
20-fruit.....	0	3	11	24	62	100	0.0	0.3	1.6	5.0	17.0	23.9
100-fruit.....	3	3	26	34	49	115	0.3	0.4	3.8	6.5	13.9	24.9
Limb.....	21	38	74	142	156	431	1.5	4.0	10.3	28.7	44.0	88.5
Vertical.....	37	92	178	334	343	984	2.4	9.1	25.0	65.0	85.6	187.1
200-pound.....	117	183	429	706	791	2,226	8.0	18.0	61.9	139.0	233.0	459.9
Remainder.....	9	16	153	128	118	424	0.9	1.6	25.5	25.0	27.2	80.2
Drops.....												
Total.....	187	336	876	1,372	1,532	4,303	13.1	33.6	128.9	270.1	424.9	870.6
(Tree 17)	0	1	4	8	7	20	0.0	0.1	0.7	1.8	1.9	4.5
20-fruit.....	1	9	30	43	15	98	0.1	0.8	4.4	8.9	3.5	17.7
100-fruit.....	17	19	35	47	31	149	1.0	1.7	4.9	9.1	7.9	24.6
Limb.....	56	125	482	214	105	982	3.6	12.5	68.7	40.9	24.5	150.2
Vertical.....	114	144	412	441	120	1,231	8.0	13.5	57.5	80.0	29.5	188.5
200-pound.....	131	191	683	931	344	2,280	9.5	18.0	92.5	177.2	80.3	380.2
Remainder.....	41	50	194	294	89	668	3.0	4.5	26.5	58.5	21.5	114.0
Drops.....												
Total.....	360	539	1,840	1,978	711	5,428	25.2	51.1	255.2	376.4	171.8	879.7
(Tree 21)	2	3	5	1	9	20	0.1	0.2	0.6	0.2	2.5	3.6
20-fruit.....	4	7	23	36	30	100	0.2	0.7	3.1	7.0	8.1	19.1
100-fruit.....	15	26	21	36	22	120	0.3	2.3	2.7	7.0	5.8	18.1
Limb.....	210	201	332	231	44	1,019	14.8	22.2	45.0	39.2	11.0	132.2
Vertical.....	145	143	392	322	164	1,165	11.5	13.5	53.0	68.0	45.5	191.5
200-pound.....	409	474	1,178	832	404	3,297	29.7	44.5	153.5	156.0	117.5	501.2
Remainder.....	16	29	126	113	51	335	0.7	2.5	17.0	21.5	14.0	55.7
Drops.....												
Total.....	801	884	2,077	1,570	724	6,056	57.3	85.4	274.9	298.9	204.4	921.4

TABLE I.—Continued

Sample	Number of Fruits in the Different Sizes					Weight of Fruit in the Different Sizes (Pounds)						
	0-1¼	1¾-2	2-2½	2½-2¾	2¾-up	Total	0-1¼	1¾-2	2-2½	2½-2¾	2¾-up	Total
(Tree 22)												
20-fruit.....	0	3	6	10	1	20	0.0	0.3	0.8	1.9	0.2	3.2
100-fruit.....	7	17	34	36	7	101	0.4	1.7	4.6	6.8	1.7	15.2
Limb.....	30	25	30	51	17	153	1.8	2.5	4.0	9.6	4.0	21.9
Vertical.....	292	188	231	185	20	916	21.0	18.6	31.4	34.5	4.7	110.2
200-pound.....	441	319	539	237	42	1,578	30.3	30.5	70.0	50.0	11.5	192.3
Remainder.....	673	395	844	863	120	2,895	46.3	37.5	126.1	138.5	33.0	381.4
Drops.....	33	14	115	108	22	292	1.7	1.5	15.1	20.5	5.0	43.8
Total.....	1,476	961	1,799	1,490	229	5,955	101.5	92.6	252.0	261.8	60.1	768.0
(Tree 28)												
20-fruit.....	4	4	10	2	0	20	0.2	0.3	1.3	0.5	0.0	2.3
100-fruit.....	14	32	36	13	4	99	1.0	3.0	4.7	2.3	0.9	11.9
Limb.....	32	50	87	37	2	208	2.3	4.7	11.7	6.6	0.4	25.7
Vertical.....	187	231	226	43	0	687	14.3	22.4	28.5	7.1	0.0	72.3
200-pound.....	522	512	678	132	2	1,846	38.3	48.5	83.0	22.0	0.6	192.4
Remainder.....	52	141	321	63	0	577	3.5	12.0	40.0	11.0	0.0	66.5
Drops.....	150	208	297	59	0	714	11.5	19.5	40.5	9.5	0.0	81.0
Total.....	961	1,178	1,655	349	8	4,151	71.1	110.4	209.7	59.0	1.9	452.1
(Total 8 trees)												
20-fruit.....	9	19	56	47	37	168	0.6	1.8	8.5	9.7	10.6	31.2
100-fruit.....	48	113	289	220	127	797	3.3	11.0	41.0	43.6	33.4	132.3
Limb.....	173	199	443	356	135	1,306	10.6	19.2	59.8	67.5	35.4	192.5
Vertical.....	1,275	1,475	2,392	1,189	350	6,681	90.7	140.8	333.5	230.7	89.8	885.5
200-pound.....	1,956	1,958	4,206	2,309	773	11,202	137.8	189.9	571.4	447.2	197.0	1,543.3
Remainder.....	3,104	3,238	8,458	5,771	2,134	22,705	218.7	316.3	1,175.3	1,077.5	581.7	3,369.5
Drops.....	392	445	1,435	1,218	391	3,881	29.0	44.1	204.2	232.8	94.1	604.2
Total.....	6,957	7,447	17,279	11,110	3,947	46,740	490.7	723.1	2,393.7	2,109.0	1,042.0	6,758.5

The remainder: After all of the different samples had been picked, the remainder of the crop was harvested and the fruit from each tree kept separate. It was from this lot that the 200-pound samples were taken.

The drops: Before the picking started, all fruit which had fallen thus far was raked away, so that the drop sample included only those apples which fell or were knocked off by the workmen in harvesting the remainder of the crop. The fruit in this sample varied in quantity, but it seemed desirable to determine how nearly the drops represented a random sample.

THE GRADING

The apples picked for the different samples were all run over a Wayland grader. The fruit above 2 inches was divided into the different size lots by this machine, and that below 2 inches in diameter was run over a specially constructed grader for the two smaller classes. In operating the graders, care was taken to see that every fruit was sized according to the diameter perpendicular to a line from stem to blossom end, i.e., the "flat" diameter. Both machines were very accurate in separating the fruits into lots varying by $\frac{1}{4}$ -inch intervals.

The accuracy of the grading was tested by determining the average size of fruit for each class in all of the different samples. In a table prepared in this way there were only two instances in which the average size of fruit in a smaller grade exceeded that in the grade larger, and both of these were in the smaller sizes where only a few fruits were involved.

THE YIELD PER TREE

In order to give a better idea of the conditions under which this study has been made, the record of the number and weight of fruit in each size and for each sample has been brought together in Table I. From this it will be noted that totals for number and weight are the summation of the seven different samples in each class.

This year (1931), on account of the unusually heavy set, there appeared to be an excess of fruit in the smaller sizes on some trees. Tree 28, a check tree which has not been pruned or fertilized for three years, was purposely included in order to test the different methods of taking samples under a wider range of conditions.

METHOD OF COMPARING THE DIFFERENT SAMPLES

There are a number of different methods of comparing the different samples with the entire crop of each tree which might have been used. Within the limits of this paper, however, it has seemed advisable to use only one of these, the "Goodness of Fit." This is a test devised by mathematicians to determine how nearly a sample, or a part of a population, approaches the total or theoretical distribution. Comparisons are made on the basis of the value of X^2 or P . When

the value of P is high, i.e., approaches unity, the sample taken represents or fits the population closely; when low, the fit is poor. Since Goodness to Fit is discussed in a number of texts on biometry, it does not seem necessary to present the method here in detail. The values for P in Tables II and III are based upon the percentage of fruit in the different samples for both number and weight—the observed reading, O , of the formula—using the percentages of the totals of each size or class as the calculated, or C , value. In this instance the fit may provisionally be looked upon as significant when the value of X^2 does not fall above three or four.

GOODNESS OF FIT OF THE DIFFERENT SAMPLES

Based upon the number of fruits: In Table II the value of P for each method of taking samples has been brought together under each tree number. Briefly summarized, it will be seen that of the different methods of sampling, the 200-pound sample and the sample representing the remainder of the fruit on the tree are best. The 20-fruit sample is fairly representative for Tree 7, but it is evident that with so few fruits even a conscious attempt to pick a representative sample is not often successful. The 100-fruit lot, selected in the same way, is but slightly more successful, and the single limb selection falls in about the same category. Likewise, with the drops which would be expected to approach a random sample, especially if the quantity were sufficient, the Goodness of Fit is generally quite low and erratic.

In view of the quantity of fruit picked from the different trees in the vertical sample (72–150 pounds) this sample would be expected to be superior to those including fewer fruits. It is on the whole quite inconsistent when compared with the 200-pound lot. Of the different samples compared, therefore, it would seem on the basis of this analysis, which is based upon the number of fruit in each class, that it would be necessary to use a method which would include a considerable proportion of the crop in order to be sure that a given treatment was being accurately evaluated.

Based upon the weight of fruit: Since it is feasible either to weigh or to count the apples picked in taking samples, it seemed advisable in this study to make comparisons by both in order to determine their relative accuracy. Accordingly, as for number, the value of P in the different samples by weight has been calculated (Table II).

It may be stated, without going into detail, that the different methods of sampling have about the same rating when the values for P are based upon weight as when based upon number. It seemed, before making the calculations, that the arrays based upon number were unbalanced for some of the trees (see Table I) and for that reason the rating of the different samples by weight would be more accurate, but the difference is apparently not significant. Since weighing takes less time than counting, this method of recording the quantity of fruit in the different classes is to be preferred if both cannot be obtained.

Based upon plot samples: So far the different samples have been compared tree by tree. Suppose that these eight trees composed a single plot and that it was impossible to grade or size all of the fruit. The question is: Can a sample of some kind be taken which will give a fairly accurate index of the influence of a treatment upon size of fruit? The different samples from each tree have been combined, kind for kind, into a single plot sample. The conditions would seem to be met, therefore, for testing the accuracy of the different samples on a plot basis. The value of P for the combined samples are summarized in Table III.

TABLE III—THE VALUE OF P FOR EACH OF THE EIGHT DIFFERENT SAMPLES COMBINED TO TEST THEIR RELATIVE ACCURACY OR FIT ON A PLOT BASIS

Value of P	Kind of Sample						
	20-fruit	100-fruit	Single Limb	Vertical Sector	200-pound	Remainder of Fruit on Tree	Drops
By number.....	.000	.013	.851	.160	.862	.955	.239
By weight.....	.037	.037	.017	.161	.854	.956	.436

From this table it will be evident that the different samples have about the same rating as in the individual tree tests. It is rather surprising to find the single limb sample of only 192 pounds and the 604 pounds of drops approximating the total more closely than the vertical sample in which there was 885 pounds of fruit. A study of the distribution of the fruit in Table I will show that in the vertical sample the proportion of the smaller sizes seems to be too large, especially in the case of fruit number. In this instance the value of P based upon weight would seem to be somewhat more accurate.

The final rating of the nearness of the approach of these different methods of taking samples in measuring a plot treatment is approximately as follows: The remainder of the fruit, the 200-pound sample, and the single limb selections. The vertical sample did not seem to approach a random selection constantly enough to be reliable. The other methods of sampling were not consistent, but in some instances approximated the true sample sufficiently closely to be representative.

CONCLUSIONS

By using the Goodness of Fit as a criterion, the fit, or accuracy, of one method of taking samples can be compared with another. From these studies it would seem that "conscious attempts" to select small representative samples are unreliable and that those methods which most nearly approximate a random sample should be used. Of the different methods tested in this study the 200-pound sample, on account of its convenience, would be most usable if the entire crop could not be sized or graded.

Variations in Shape of Bartlett Pears

By W. P. TUFTS, and C. J. HANSEN, *University of California, Davis, Calif.*

ONE of the most important requirements in the making of a satisfactory delivery of Bartlett pears to Pacific Coast canneries is that the fruit be "well formed." The Northwest Canners Association, in its "1931 Standards for Pears for Canning," states "*Well formed* means that the pears shall have a shape characteristic of the variety, of a length not less than $1\frac{1}{3}$ times the diameter of the pear, and which shall cut into two well formed peeled halves." Any fruit not meeting this requirement as to shape was accepted only as a "cull." The requirements of the California canners were not so drastic inasmuch as deliveries were required to average $1\frac{1}{4}$ times as long as broad, and no pear less than $1\frac{1}{8}$ times as long as broad was accepted as other than a cull. The question of "apple-shaped" or "short" Bartlett pears has become of increasing economic importance to California growers during the past several years. Some orchardists have had as high as 25 per cent of their crops graded as culls on account of the pears being too short.

This problem has been attacked by the establishment of definite experimental plots where the influence of such factors as root-stocks, pruning, irrigation, and fertilizers are being studied and by a survey of some 20 pear growing sections of California, Oregon, and Washington, with the hope that it might be possible to correlate some common factor existing in these different districts with the shape of the Bartlett pear fruit. These studies were initiated in the spring of 1930 and enlarged in scope during the 1931 season.

During the season of 1931 representative samples of fruit from orchards in 20 different pear sections of the Pacific Coast were measured and ratios of maximum length to maximum transverse diameter determined (L/D ratio). In practically every orchard 100 fruits, 10 pears from each of 10 trees, were used. These data are briefly summarized in Table I.

A clearer appreciation of what these ratios mean in shape of fruit will be gained from an inspection of Fig. 1. These fruits all have practically the same transverse diameter but with length-to-diameter ratios varying from 1.10 to 1.54. Pear No. 1 is a typical "apple-shaped" Bartlett without neck and not quite long enough to be accepted by the California canneries in 1931. Pear No. 2 has a L/D ratio of 1.22 and is just under the 1931 requirement of the California canneries that Bartlett pears must average $1\frac{1}{4}$ times as long as broad. Pear No. 3 is relatively just a little longer than the 1931 minimum requirement of the Northwest Canners Association. Pear

TABLE I.—LENGTH TO DIAMETER RATIOS OF BARTLETT PEARS (PACIFIC COAST PEAR DISTRICTS, 1931)

Antelope Valley Los Angeles County	Alameda, Santa Clara, and San Benito Counties	Sacramento Delta; Sacramento, Yolo, Solano and Contra Costa Counties	Placer County	Interior Sacramento Valley; Sutter and Yuba Counties	El Dorado County	Vacaville Solano County	Lake and Mendocino Counties	Berryessa Valley Napa County	Medford, Oregon	Hood River, Oregon	Yakima, Washing- ton
1.17	1.17	1.13	1.18	1.27	1.27	1.31	1.41	1.41	1.43	1.43	1.43
—	1.23	1.18	1.23	1.28	1.32	1.30	1.44	1.37	1.40	1.48	1.45
—	1.21	1.14	1.24	1.22	1.18	1.29	1.39	1.45	—	—	1.57
—	1.15	1.25	1.19	1.24	1.28	—	1.35	—	—	—	—
—	1.12	1.24	1.17	1.20	1.26	—	1.37	—	—	—	—
—	1.21	1.16	1.14	1.21	1.28	—	1.33	—	—	—	—
—	1.16	1.17	—	—	—	—	1.36	—	—	—	—
—	1.22	1.17	—	—	—	—	1.34	—	—	—	—
—	1.13	1.14	—	—	—	—	1.37	—	—	—	—
—	1.26	1.11	—	—	—	—	—	—	—	—	—
—	1.13	1.20	—	—	—	—	—	—	—	—	—
—	1.19	1.21	—	—	—	—	—	—	—	—	—
—	1.25	1.24	—	—	—	—	—	—	—	—	—
—	1.18	1.29	—	—	—	—	—	—	—	—	—
—	—	1.23	—	—	—	—	—	—	—	—	—
—	—	1.12	—	—	—	—	—	—	—	—	—
—	—	1.18	—	—	—	—	—	—	—	—	—
—	—	1.21	—	—	—	—	—	—	—	—	—
Average											
1.17	1.19	1.19	1.19	1.24	1.27	1.30	1.37	1.41	1.42	1.46	1.48

No. 4 is a typical Bartlett of certain districts in the Pacific Northwest.

The data presented in Table I show that there is a great difference in the relative length of Bartlett pears in various pear growing

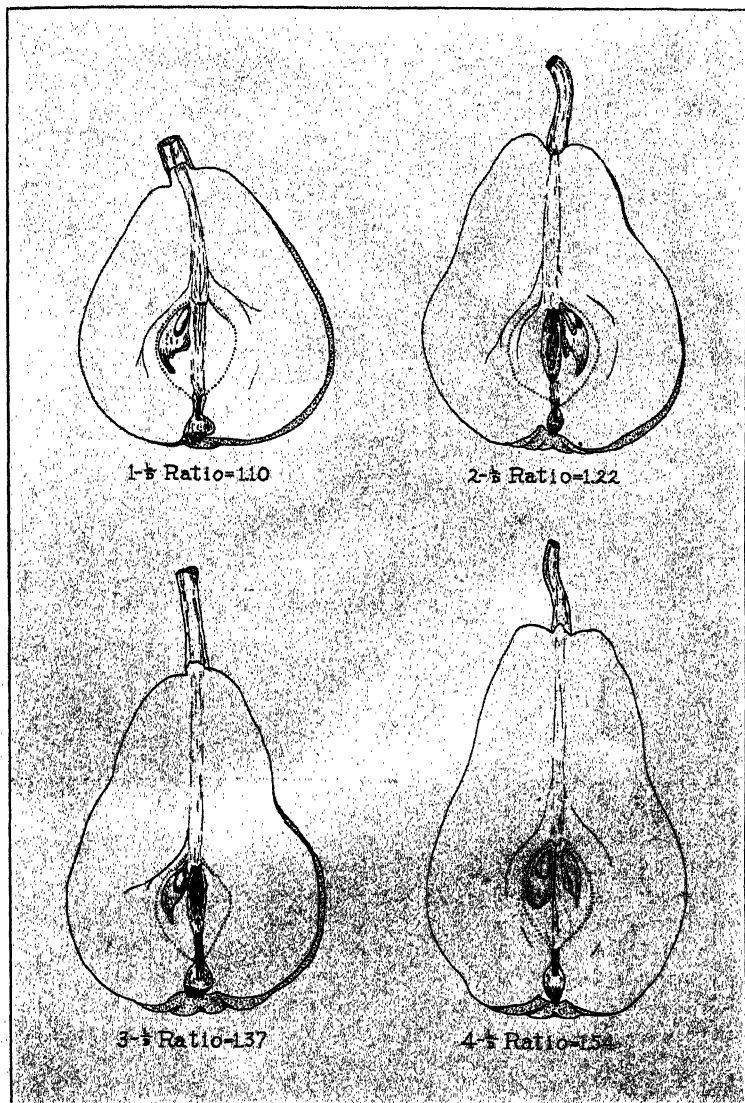


FIG. 1. Drawings of longitudinal sections of Bartlett pears showing typical length to diameter ratios ($\times 2/3$).

sections. This fact has also been pointed out by Putterill (1) for South African districts. It is likewise to be noted that in addition to the Antelope Valley in Los Angeles county and Placer county that those portions of San Benito, Santa Clara, Alameda, Contra Costa, Solano, Sacramento, and Yolo counties located near San Francisco Bay, or where ocean influences prevail, produce the shortest fruits. It may be stated that with a few exceptions the longest

TABLE II—EFFECT OF AGE OF SPUR ON L/D RATIO OF BARTLETT PEARS

Orchard	Location	Year	Root-stock	Age Years	Pruning Treatment	L/D Ratio
Danielson....	Suisun	1931	French	30	Old ¹ spurs removed	1.32±.006
Danielson....	Suisun	1931	French	30	Young ² spurs removed	1.21±.006
McConaghey.	Hayward	1931	French	12	Old spurs removed	1.22±.008
McConaghey.	Hayward	1931	French	12	Young spurs removed	1.13±.006
McConaghey.	Hayward	1930	French	11	Old spurs removed	1.16±.008
McConaghey.	Hayward	1930	French	11	Young spurs removed	1.12±.008
F. H. Buck...	Vacaville	1931	French	30	Old spurs removed	1.31±.007
F. H. Buck...	Vacaville	1931	French	30	Young spurs removed	1.30±.007

¹Five or six years and older.²Less than five or six years.

fruit is found at the higher latitudes. It is the common experience of fruit packers that it takes at least 180 Bartlett pears $2\frac{3}{8}$ inches in diameter, as grown in the Sacramento delta, to make a 52-pound pack in a standard pear box, 163 pears in Lake county or Medford, Oregon, and only 150 pears of the same variety and diameter in Yakima, Washington. These experiences of the fruit packers are verified by the ratios secured in these districts.

Growers of Bartlett pears in those districts immediately adjacent to San Francisco Bay have experienced the greatest difficulty with short pears. The orchard of Mr. E. A. Nelson near Santa Clara is in one of these short pear districts. This orchard, possibly 35 to 40 years of age, has always had the reputation of producing high quality canning fruit of good length (Plate I). During the season of 1931 this orchard had an average L/D ratio of 1.42. Some 15 years ago Mr. W. S. Bennett also of Santa Clara planted a Bartlett pear orchard which has consistently produced long fruit. In 1931 the L/D ratio of this latter orchard was 1.36. Upon investigation it was found that the buds for the Bennett orchard had been secured from the Nelson orchard by the Jackson Nursery, of Santa

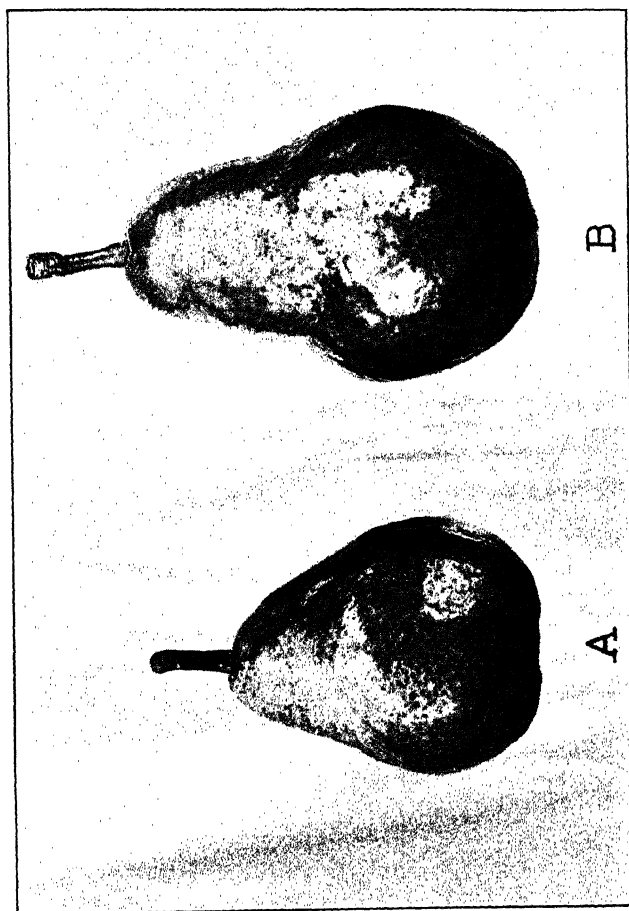


PLATE I. Pear A is a well grown Santa Clara Valley Bartlett considerably above the average in length for the district. Pear B is a "Nelson Bartlett" grown in the same district as fruit A. Compare the relative lengths.

Clara. It seems reasonable to suppose that these two orchards since they produce fruit distinctly different in shape from that of all the other Bartlett orchards observed in the same section are of a distinct "strain." No early history of this supposed "sport" could be secured. On the other hand, Mr. Arthur Karr of Yakima, Washington, has a Bartlett tree on which for a number of years one "sport" branch has produced larger and relatively shorter pears

TABLE III—LENGTH TO DIAMETER RATIOS OF BARTLETT PEARS IN RELATION TO ROOTSTOCK

Orchard	Location	Year	Rootstock	Age in Years	L/D Ratio
Pyle.....	San Benito County	1930	French	15	1.26±.011
Pyle.....	San Benito County	1930	Japanese	15	1.05±.009
Pyle.....	San Benito County	1931	French	16	1.25±.010
Pyle.....	San Benito County	1931	Japanese	16	1.18±.009
Nutting...	San Benito County	1931	French	8	1.19±.006
Nutting...	San Benito County	1931	Japanese	8	1.13±.006
Hunter....	Santa Clara County	1930	French	17	1.20±.006
Hunter....	Santa Clara County	1930	Japanese	17	1.10±.007
Hunter....	Santa Clara County	1931	French	18	1.15±.006
Hunter....	Santa Clara County	1931	Japanese	18	1.12±.005
Knowles...	Berryessa Valley	1931	French	12	1.41±.011
Knowles...	Berryessa Valley	1931	Japanese	10	1.37±.010
Benson....	Lake County	1931	French	26	1.41±.008
Benson....	Lake County	1931	Japanese	13	1.44±.009

than the balance of the tree. This would seem to indicate that the relative length of the fruit might be a "character" subject to modification by a bud mutation. Plans for top-working trees now producing a high percentage of "short" fruit with scions from the Nelson orchard have been made.

A pruning system which constantly removes the old spurs and saves the new fruiting wood is of help in securing longer fruit in those districts where there is a tendency to produce a large percentage of short or apple-shaped pears. See Table II.

It will be noted that in the first two orchards the removal of old spurs helped somewhat in securing longer fruit. At Vacaville, where relative length is not a problem, no benefit resulted from the differential treatment. This was also true in the McConaghey orchard at Hayward, in 1930. Rather extensive observations, however, lead to the conclusion that the young fruit wood will in general produce a relatively long pear.

Possibly more than 30 per cent of the pear trees in California are on Japanese (*Pyrus serotina*) root. In San Benito and Santa

Clara counties where conditions are such that a large percentage of the fruit is short, the Japanese root in some seasons tends to aggravate the trouble. In sections such as the Berryessa Valley and in Lake county where the relative length of the fruit is no problem the influence of the Japanese root on shape is not consistent. See Table III.

TABLE IV—SEED CONTENT AND L/D RATIO (BARTLETT PEARS 1931)

District	Diameter (mm.)	Length (mm.)	L/D Ratio	No. of Seeds per Fruit	Remarks
British Columbia.	58.5	85.2	1.46	5.4	
Sebastopol, Calif.	67.9	84.1	1.24	1.5	
Davis, Calif.	74.6	91.6	1.23	3.0	
El Dorado County	71.6	91.3	1.28	2.1	
Berryessa Valley.	62.8	93.1	1.48	1.2	French root. Frost injury in this block
Berryessa Valley.	63.9	90.3	1.41	5.5	Japanese root
Hood River, Ore..	68.5	98.2	1.43	6.0	French root
Hood River, Ore..	70.1	104.0	1.48	4.8	Japanese root
Antelope Valley..	66.7	78.3	1.17	2.4	
Mendocino Co. ...	64.6	86.4	1.34	0.3	Frost injury in this block
Yakima, Wash. ...	65.6	102.7	1.57	1.2	Heavy dust storm during pollination period
Lake County.	65.4	89.6	1.37	0.5	Some frost injury
Sutter County.	60.3	72.3	1.20	5.7	Cross pollinators present
Sutter County.	60.5	73.0	1.21	1.6	No provision for cross-pollination

Much has been written about the influence of seed upon the development of the fruit. Data (Table IV) secured during the 1931 season with Bartlett pears seem to indicate that there is no correlation between seed content and the ratio of length to diameter of the fruit. This is strikingly shown by the data for the two orchards in Sutter county which are the same in age, on the same rootstock, growing on the same soil type and under identical cultural conditions except that one orchard is interplanted with another variety to secure cross pollination of the Bartlett.

Data on the specific influence of "bud-mites", soil differences, nitrogenous fertilizers, irrigation practices, size of crop, altitude, humidity, and temperature on the shape of the Bartlett pear fruit are not sufficient at this time to warrant conclusions. Apparently the shape of the fruit of this variety varies with the district in which it is grown. In certain sections and in some seasons somewhat longer fruit may be secured from trees on French root than from trees on Japanese root, and also, from young fruiting wood rather than from old spurs. At the present time it appears that the best procedure for those sections typically producing a relatively short pear, is to grow a particular strain of Bartlett which meets the artificial requirement of the trade for a long fruit. The "Nel-

son" strain of Bartlett gives every indication of meeting this requirement.

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Black-End and Its Occurrence in Selected Pear Orchards

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THE occurrence of black-end of pears has been reported from Oregon (1), from California (2), and from South Africa (3). In two of these cases (2, 3) the trouble has been associated with the *Pyrus serotina* rootstock. The trouble in South Africa was first noticed about 1900, when trees, which were planted prior to that time, came into bearing. The condition made its appearance annually but did not seem to spread to other trees. However, about 1927 it seems to have made its appearance in orchards which were planted about 1900 but which had not previously shown black-end. On individual trees the number of affected fruits is reported as ranging from 10 to 100 per cent. Heppner (2) has reported the number of affected fruits on individual trees as ranging from 9.5 to 100 per cent. He also found that the number of black-end fruits varied in different years, and that in a few cases individual trees might produce black-end fruit one year and normal fruit the next. His data are only for two years.

Since the value of our samples for chemical and histological work depended upon the subsequent behavior of the tree with respect to black-end it was important that we know the performance of individual trees. Not only was it necessary that we know the performance of the individual trees in any one season of our sampling but it would be highly desirable if we could forecast the performance of a tree from year to year. In addition it was important to know whether the trouble was spreading throughout an orchard or whether the same number of trees were affected from year to year.

In 1929 records were made of the performance of individual trees in several orchards and these same trees have been mapped with respect to the occurrence of black-end each year since. The data presented in this paper were obtained during this survey.

It has been found difficult to estimate the amount of black-end on any tree with much accuracy since the number of fruits actually showing black-end depends upon when the estimate is made. Not only do more fruits show black-end as the season advances but also large numbers of the affected fruits fall. The maps were made as near the picking season as possible each year and the amount on each tree relatively classed as follows: very few, some, one-fourth, one-half, three-fourths and "bad" black-end. The "bad" black-end referred to a situation in which most or all of the fruits were black-end fruits. No attempt has been made to estimate the severity of the black-end condition on individual fruits, but only to estimate the relative number of black-end fruits per tree. Each year the map of an orchard was made without reference to the per-

formance record of the previous year. The orchards are representative of nearly all of the pear growing sections of the state.

Fig. 1 shows the distribution of the black-end trees in an orchard which is representative of those mapped. It also shows the consistency of performance of the individual trees. The numbers 29, 30, 31 indicate the years when the trees have had black-end. The absence of these figures indicates the absence of the black-end condition for those years. The blank spaces indicate trees on Japanese root that have shown no black-end fruits during these three years. The letter F indicates trees on French root.

The distribution of the black-end trees over the block seems to be entirely random in nature. There are no areas of any size where only black-end or normal trees occur. This random distribution is typical of all orchards which we have mapped or observed. Likewise the severity of the condition on any one tree seems to be entirely random in nature. A tree that has fallen into the "bad" black-end group each year may be adjacent to a tree that apparently has never produced any black-end fruits. We have assumed this random distribution to indicate that factors which are not associated with soil variability are quite important in the production of black-end fruits. This random distribution is typical of all pear growing sections in the state whose soils may differ widely from one another.

The performance of individual trees is in sharp contrast to the random distribution of the black-end trees over an area. The performance records indicate that individual trees are very consistent in their performance. Table I presents the data for the orchards which have been mapped. The data for orchards which have been mapped less than three years are also included for the purpose of showing the per cent of trees having black-end.

In nearly all cases a large percentage of the affected trees have shown black-end each year of the mapping. In the case of the orchards which have been mapped for three years a much smaller percentage of trees have had black-end for two years than the number affected for all three years. Likewise, a relatively small percentage of the trees have had black-end for only one year out of the three. Those trees which have had black-end for but one year have, with very few exceptions, been trees that have had comparatively few black-end fruits. No trees which were classed as "bad" black-end in 1929 have failed to produce black-end in 1930 and 1931. The Hill and Swett orchards have had the largest number of trees which have not been consistent performers. They have likewise been the orchards where the black-end condition has been less on individual trees.

The percentage of trees producing black-end is shown in the last column of Table I. On trees on Japanese rootstock there is very close agreement among the different orchards in respect to the relative number of trees producing black-end. The effect of some other rootstocks is also shown in the last column. The Danton orchards give a good comparison between the percentage of trees

TABLE I.—SUMMARY OF PERFORMANCE RECORDS OF BARTLETT PEAR TREES WITH RESPECT TO THE OCCURRENCE OF BLACK-END

Orchard	Age in Yrs.	Location County	Rootstock	Total No. Trees	No. Yrs. Mapped	No. Trees Showing Black-end in			No. Trees Showing Black-end for			Total No. Black-end Trees	Per cent Black-end Trees
						No. Trees Showing Black-end in			No. Trees Showing Black-end for				
						1929	1930	1931	3 yrs.	2 yrs. only	1 yr. only		
Swett.....	20	Contra Costa	Kieffer seedling	553	3	69	81	82	67	12	18	97	17.5
Havside.....	8	Contra Costa	Japanese	200	2	—	80	81	—	71	21	92	46.0
Dantoni.....	14	Yuba	P. ussuriensis	80	1	—	—	5	—	—	5	5	6.2
Dantoni.....	14	Yuba	Japanese	78	1	—	—	21	—	—	21	21	27.0
Bentley.....	12	Napa	Japanese	185	3	92	99	94	87	13	2	102	55.1
Elliott.....	11	Sacramento	Japanese	240	3	80	89	89	75	13	8	96	40.0
Toepelman...	15	Sacramento	Japanese	255	3	105	114	110	94	12	16	122	47.8
Staten Island	12	Sacramento	Japanese	175	3	92	99	80	71	22	12	105	60.0
Tadlock-Myszka (old)	20	Mendocino	Japanese	135	2	—	55	56	—	55	1	56	41.5
Tadlock-Myszka													
(young).....	7	Mendocino	Japanese	80	3	17	30	30	17	11	3	31	38.7
Hill.....	16	Lake	Japanese	160	3	36	32	40	18	22	18	58	36.2
Stone.....	12	El Dorado	Japanese	326	1	—	—	121	—	—	121	121	37.1
Hunter.....	16	Santa Clara	Japanese	318	2	—	158	133	—	124	34	158	49.6
Bennett.....	14	Santa Clara	Japanese	180	1	—	—	111	—	—	111	111	61.6

which produce black-end on *P. ussuriensis* and on *P. serotina*. The trees on these two rootstocks alternate with each other in the row and are 12 feet apart. There are relatively $4\frac{1}{2}$ times as many black-end trees on the Japanese rootstock as on the Ussuriensis. The trees propagated on Kieffer seedling rootstock produce relatively few black-end trees, being next to Ussuriensis in this respect.

[illegible]

FIG. 1. Elliott orchard, showing distribution of black-end trees.

Neither Fig. 1 or Table I indicates the severity of the black-end condition on individual trees. Our records show that there is a remarkable consistency of performance. The trees continue to fall in the same or nearly the same classes each year. That is the trees which have been classed as producing large numbers of black-end fruits one year have produced large numbers of black-end fruits for each of the other years, while trees producing small numbers of black-end fruit one year have in general done so for the other years.

Although our observations are only for the season of 1931 there seems to be a difference in time among individual trees when actual black-end fruits are visible. This was when the trees were in the same orchard. Likewise there seems to be a difference between the main scaffold branches of the same tree. The trees which produced the largest number of black-end fruits were the first ones on which black-end fruits were found during the season of 1931. Also observations on one tree indicated that one scaffold branch had black-end fruit about ten days before the other two branches. In this case the branch showing the black-end first had the largest percentage of its fruit affected.

CONCLUSIONS

Individual tree records have been made in a number of orchards where black-end occurs. The distribution of the affected trees in the orchard seems to be of an entirely random nature. Trees that produced black-end fruit one year continued to do so each year with a high degree of consistency. The relative severity of the black-end condition on any tree is repeated from year to year. The records were made in orchards on *P. serotina*, *P. ussuriensis*, and Kieffer seedling rootstocks. The *P. serotina* rootstock produced the greatest number of black-end trees, the Kieffer seedling the next greatest.

and the trees on *P. ussuriensis* produced the least. Differences in the time of appearance of black-end fruits on individual trees were observed in 1931. The first black end fruits were found on trees that had large numbers of affected fruits during this season.

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Maturity and Rate of Ripening of Gravenstein Apples in Relation to Bitter Pit Development

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THE Gravenstein is the most important summer apple grown in California and as the first boxed apple of the season it is in demand both on home and foreign markets. Unfortunately, it is a variety which is very susceptible to bitter pit. Regardless of different views as to whether or not bitter pit has its inception before the fruit is picked, the characteristic spotting is rarely conspicuous or even noticeable when the fruit is harvested. The trouble, however, frequently develops rapidly in transit, resulting in the apples being of unsightly appearance when offered for sale.

TABLE I—THE INFLUENCE OF MATURITY WHEN HARVESTED UPON THE DEVELOPMENT OF BITTER PIT IN GRAVENSTEIN APPLES, 1926

Date Harvested	Firmness of Fruit, (Pounds Pressure)*	Color of Fruit†	Per cent Bitter Pit 20 Days After Harvest
June 25	18.7	1½-2	52.0
July 2	17.4	2-2½	50.0
July 8	17.3	2-2½	38.0
July 22	9.8	3-3½	5.0

*Using a ¼-inch plunger point, fruit pared.

†Figures refer to different shades of green on color chart published in U. S. D. A. Dept. Bul. 1406, 1926.

TABLE II—THE INFLUENCE OF MATURITY WHEN HARVESTED AND STORAGE TEMPERATURE UPON THE DEVELOPMENT OF BITTER PIT IN GRAVENSTEIN APPLES, 1930

(Figures in percentage)

Date Harvested	Fruit Stored 10 Days at 50° F.		Fruit Stored 10 Days at 70° F.	
	On Removal from Storage	After Ripening 12-15 Days at 70°	On Removal from Storage	After Ripening 10 Days at 70°
June 30	52.0	65.0	0.0	3.0
July 14	22.0	30.0	0.0	0.0
July 29	0.0	7.0	0.0	5.0

The more recent investigations of Brooks and Fisher (4), Adam (1, 2), Smith (9), and Carne (5, 6, 7), as well as several years' results from the California Agricultural Experiment Station have shown that apples harvested in an immature condition are more susceptible to bitter pit than those harvested after they show some visible signs of ripening. Brief data supporting these findings were presented by Overholser (8) in 1927. Further evidence that proper maturity at the time of harvesting is an important factor with the California Gravenstein, is presented in Table I, which gives the results obtained by Magness and the writer from several representative orchards in the Sebastopol district in 1926. Table II gives the results obtained from some of the same orchards in 1930. These data on fruit

picked at intervals of from one to two weeks from selected trees show a very definite decline in the amount of bitter pit development as the season advances. In fact the amount and the severity of bitter pit in the last pickings was negligible.

During the past season no definite attempt was made to substantiate further the above findings. However, a comparison of commercial samples collected June 25, July 7, and July 23, for ripening studies, showed that the fruit harvested on the last date again developed materially less bitter pit. The samples collected on June 25 and July 7, the latter date being only a few days after the general beginning of commercial harvest, showed little difference in the amount of bitter pit development.

THE EFFECT OF STORAGE TEMPERATURE AND RATE OF RIPENING ON BITTER PIT DEVELOPMENT

A low storage temperature is generally regarded as having a retarding effect upon the development of bitter pit. It appears, however, that there are some exceptions to this, and even where the minimum amount of bitter pit is observed while the fruit is under low temperatures, different results may be secured after it is removed to a higher temperature for ripening.

Adam, working in Australia with Dunn's Seedling and Anne Elizabeth apples reports that the former variety, after being stored eight months, showed less bitter pit at 32 degrees F. than comparable lots held at 34 degrees. Smith, using Ribston Pippin and the Cox's Orange varieties grown in Tasmania, noted less bitter pit development, after 30 days, at 33 to 34 degrees F. than at 50 to 70 degrees. In contrast, however, he presents the results of Carne, who, working with the Cleopatra variety grown in Western Australia, found more than twice the amount of bitter pit after 30 days at 33 to 34 degrees F. than he did after the same period at 60 to 80 degrees. Commenting upon his own results, Smith ventures the assumption that possibly the fruit held at 32 to 34 degrees might eventually have developed a greater amount of bitter pit than that held at 50 to 70 degrees.

In the past few years, Carne has published several papers on bitter pit and in 1927 offered the theory that the disease was "a necrosis of immature starch-filled tissues of rapidly growing apples resulting from excessive transpiration, followed by osmotic action between the starch-filled cells and those in which the starch has been largely or completely changed to sugar." He points out that the ripening of apples is uneven and that the bitter pit tissues contain starch. If this theory is correct is it not reasonable to expect that bitter pit can be reduced by speeding up the ripening process rather than retarding it? In a previous paper the writer (3) reported that Gravenstein apples held for immediate ripening developed less bitter pit under a temperature of 70 degrees F. than they did at 50 degrees. This statement is supported by the data shown in Table II.

To further test the accuracy of these results, box lots of Gravenstein apples were again secured in 1931 from nine different orchards

in the Sebastopol region and held for 10 days (the time required for shipments to reach the eastern markets) at temperatures of 32 degrees, 50 degrees, and 70 degrees F. Following this initial 10-day period at the above temperatures, all samples were observed for bitter pit development and then removed to a basement temperature of 70 to 75 degrees for ripening. Subsequent observations were made at 10-day intervals. Specimens showing only a few rather inconspicuous spots were classified under "slight" bitter pit, while those where the severity of the trouble was sufficient to materially influence their economic value were classed as "severe."

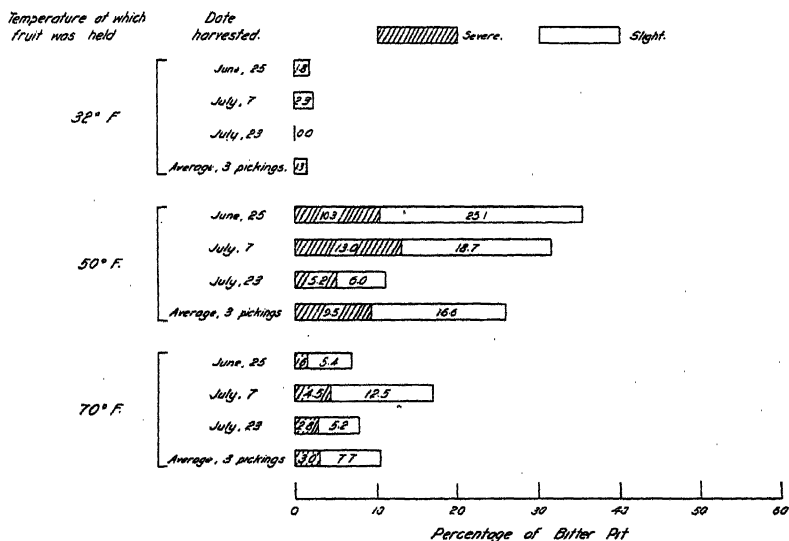


FIG. 1. The influence of temperature on the development of bitter pit in Gravenstein Apples 10 days after harvesting.

Fig. 1 illustrates the development of the disease after holding for 10 days at the temperatures indicated. While clearly showing the retarding influence of low temperatures it also shows that much less bitter pit has developed under a temperature of 70 degrees than at 50 degrees.

Fig. 2 shows the continued development of bitter pit after an additional 10 days ripening at 70 degrees. The severity of the disease on the three lots originally held at 32, 50, and 70 degrees remains in the same order as in Fig. 1. Marked gains in slight bitter pit, however, have taken place in the samples originally held at 32 degrees, and the rate of development continued to increase until after an additional 10-day period (30 days after harvesting) when these samples showed a percentage of infection nearly as great as the fruit originally held at 50 degrees. Both of these lots now show more severe spotting than the fruit held continuously at 70 degrees (Fig. 3.) At

this time, however, the fruit held continuously at 70 degrees was yellow, overripe, and beginning to show some physiological breakdown.

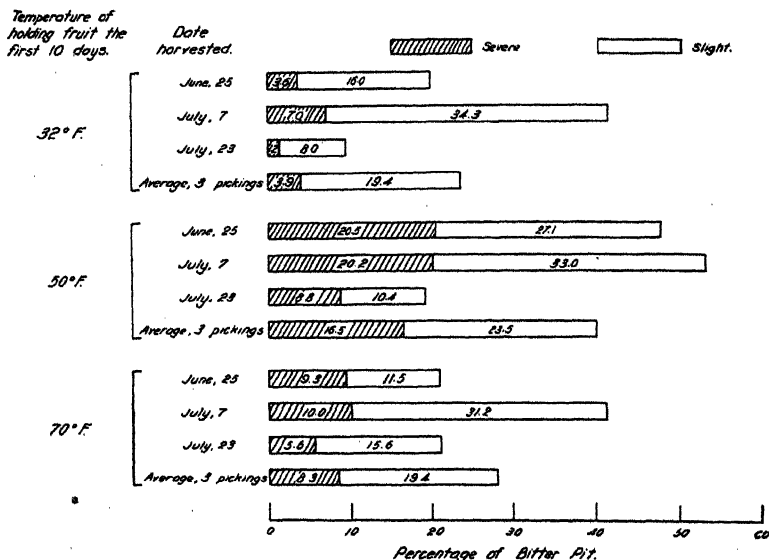


FIG. 2. Same as Fig. 1. after all samples had been held an additional 10 days at 70 degrees F.

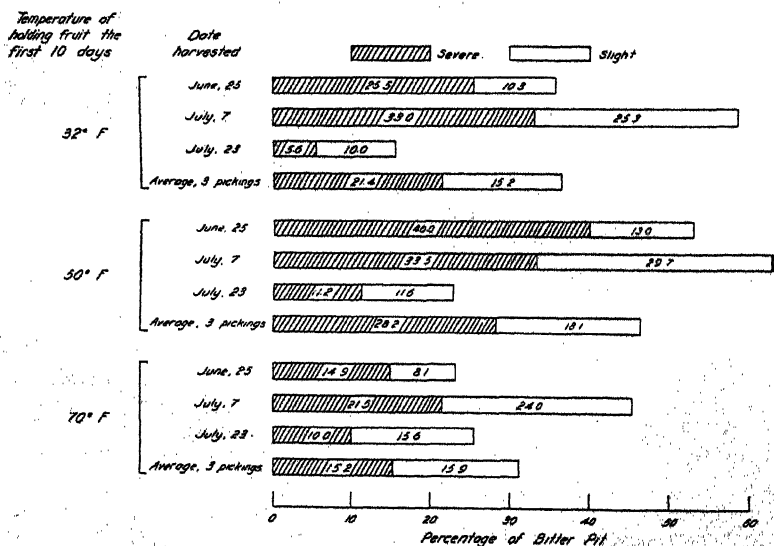


FIG. 3. Same as Fig. 1 after all samples had been held an additional 20 days at 70 degrees F.

Fig. 4 is therefore presented to show the percentage of bitter pit existing at the time when each sample was considered to have first reached its prime eating condition. The period for the different samples to reach this condition varied from 25 to only 11 days. The samples which ripened continuously at 70 degrees were again in

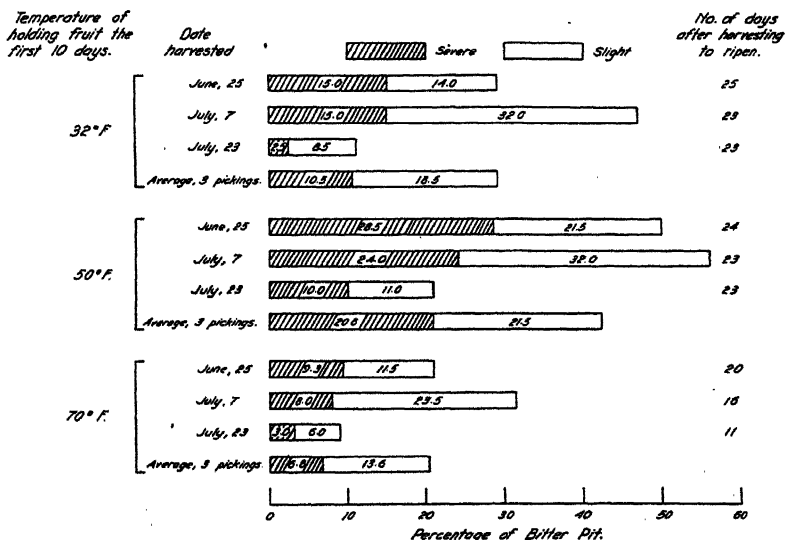


FIG. 4. Same as Fig. 1 but fruit in prime eating condition.

somewhat better condition than those stored for 10 days at 32 degrees, and materially better than those held at 50 degrees. Two years' tests therefore seem to indicate (a) that while a low temperature of 32 degrees will retard bitter pit, its development on immature fruit after removal from storage will be rapid, and (b) fruit harvested and held continuously at a temperature of 70 degrees or higher will develop the minimum amount of bitter pit at and during the time it is in the best condition for eating.

Whether these results can be explained wholly on the basis of Carne's theory, might well be open to question without more extensive tests than have been conducted. Table III, however, shows that Gravenstein apples after 10 days ripening at 70 degrees contain, on the average, only half as much starch as comparable lots held for 10 days at 50 degrees. No analyses were made of samples stored for 10 days at 32 degrees but it is reasonable to assume that the starch content would have changed but little from that when picked.

HASTENING RIPENING WITH ETHYLENE

Since ethylene hastens the disappearance of starch, as shown in Table III, it seems logical to inquire whether or not treated apples develop less bitter pit than those not treated. Trials made in 1930,

previously mentioned, indicated that ethylene did materially reduce the percentage of bitter pit with samples held for 10 days under a temperature of 50 degrees F. However, of six orchards from which fruit was harvested, samples from only two developed enough bitter

TABLE III—PERCENTAGE OF STARCH IN GRAVENSTEIN APPLES, 1930

Sample No.	When Harvested	After 10 Days			
		Natural Ripening		Ripening with Ethylene	
		At 50° F	At 70° F	At 50° F	At 70° F
1	1.49	0.74	0.33	0.53	0.20
2	1.00	0.36	0.26	0.34	0.23
3	1.69	0.90	0.44	—	0.25
4	1.33	0.56	—	0.45	0.27
5	1.16	0.30	0.11	0.28	0.11
6	1.23	0.62	0.11	0.28	0.10
7	1.16	0.48	0.10	0.25	0.09
8	1.12	0.46	0.21	0.36	0.17
9	1.31	0.74	0.24	0.65	0.24
10	1.26	0.52	0.30	0.43	0.19
11	1.33	0.58	0.25	0.39	0.17
Average	1.28	0.57	0.23	0.39	0.18

pit in the untreated lots to make the differences marked. Additional tests during 1931, giving only three treatments of ethylene (1-1000) during a 10-day period proved insufficient to cause any response of the fruit held at 50 degrees F. Table IV gives the average responses of five samples of early picked fruit treated at 70 degrees. Although the rapid rate of ripening characterizing fruit held at 70 degrees resulted in a relatively low percentage of bitter pit even in the untreated samples, the results indicate that the ethylene may have had some value. More marked results might have been secured from daily applications of the gas.

TABLE IV—PERCENTAGE OF BITTER PIT DEVELOPMENT IN GRAVENSTEIN APPLES AS INFLUENCED BY 10 DAYS ETHYLENE GAS TREATMENT. FRUIT HARVESTED JUNE 25, 1931

Days Following Harvest	Treated Samples			Untreated Samples		
	Slight	Severe	Total	Slight	Severe	Total
10.....	2.2	0.0	2.2	5.7	0.7	6.4
20.....	8.0	2.0	10.0	9.9	4.4	14.3
30.....	5.2	7.4	12.6	7.0	10.0	17.0

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Notes on the 1930 Drought in West Virginia Orchards¹

By LEIF VERNER, *University of West Virginia, Morgantown, W. Va.*²

WEST Virginia experienced in 1930 the most severe drought in the history of its Weather Bureau records. Serious damage to native vegetation, farm crops, and orchards was general throughout the state. The present paper, however, concerns only the eastern panhandle. Except as otherwise indicated, the weather statistics cited refer to the station at Martinsburg, in the northern part of the Shenandoah Valley. Conditions at that station were representative of conditions throughout most of the eastern West Virginia fruit region.

From January 1 to December 1, 1930, precipitation at Martinsburg was below normal for every month except June (Table I). After midsummer much of the rainfall recorded came in such small amounts that it evaporated from the hot, dry soil before penetrating to the depth of living roots. To further aggravate the situation the mean and maximum temperatures and the percentage of sunshine were much above average. The most severe period of subnormal precipitation, occurring during the critical months of July and August, was followed by continued subnormal rainfall until December, and by a September mean temperature 7 degrees above the average. Total precipitation for the 8 months from March to October, inclusive, was 13.9 inches—slightly more than half the normal.

Peach trees on the whole suffered little permanent injury. Late frost destroyed the crop in most of the state and this possibly helped the trees through the drought. A few orchards near Martinsburg with good crops, however, showed no signs of injury other than reduced growth and undersized fruit. Severe injury and death of trees occurred in a few instances on very shallow soils, but these cases were exceptional. Greater injury was apparent in peach orchards the year following, when the fruit in many instances was below average size, ripened more unevenly than usual, and was of poor quality.

Montmorency cherries, most of which in this region are under 5 years of age, showed little injury in 1930 other than retarded terminal growth. In 1931 the fruit ripened slowly and more unevenly than usual. In an occasional instance in which small twigs had died, some root injury was observed. Roots an inch in diameter showed patches of dead tissues but were otherwise sound. Numbers of roots of $\frac{1}{4}$ -inch or less in diameter, usually within 6 inches of the surface, were killed.

Apple trees suffered greater injury than peaches and cherries. In extreme cases blocks of 500 to 800 trees, largely Ben Davis, were completely killed or so badly damaged that they have been abandoned. A few trees were found dead as early as August. These trees usually had

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²Located at University Experiment Farm, Kearneysville, W. Va.

TABLE I--TEMPERATURE AND PRECIPITATION OF SELECTED STATIONS.

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Martinsburg, W. Va. 1930.....	1.44	2.23	2.76	2.47	0.92	3.13	1.28	1.08	1.79	0.47	0.75	3.11	21.43
normal.....	2.21	2.43	3.30	3.04	4.00	2.49	3.78	3.81	2.87	2.56	2.26	2.73	35.48
departure, 1930....	-0.77	-0.20	-0.54	-0.57	-3.08	+0.64	-2.50	-2.73	-1.08	-2.09	-1.51	+0.38	-14.05
Kalmar, Sweden normal.....	.9	.7	.9	1.0	1.2	1.4	1.8	1.9	1.6	1.5	1.4	1.1	15.4
Moscow, Idaho normal.....	2.82	2.11	2.06	1.55	2.35	1.31	0.70	0.74	1.27	1.62	3.05	2.49	22.07
The Dalles, Oregon normal.....	3.01	2.08	1.44	0.69	0.65	0.54	0.21	0.19	0.80	1.09	2.57	3.08	16.35
Mean Temperature (Degrees Fahrenheit)													
Martinsburg, W. Va. 1930.....	30.6	37.4	41.0	50.0	65.6	72.6	79.0	74.7	73.2	53.2	44.6	31.2	54.4
normal.....	30.5	30.0	41.3	51.5	63.1	70.6	75.3	73.0	66.1	54.6	42.7	32.7	52.6
departure, 1930....	+0.1	+7.4	-0.3	-1.5	+2.5	+2.0	+3.7	+1.7	+7.1	-1.4	+1.9	-1.5	+1.8
Kalmar, Sweden normal.....	30.0	30.0	32.0	39.0	48.0	58.0	62.0	61.0	55.0	46.0	38.0	32.0	45.0
Moscow, Idaho normal.....	28.4	31.3	37.7	46.0	52.0	58.3	66.5	65.7	57.7	48.1	37.6	31.0	46.6
The Dalles, Oregon normal.....	32.3	37.8	45.7	53.2	60.1	66.3	72.2	71.2	62.7	53.2	42.3	35.2	52.7

retained their foliage, which had dried out and turned brown. Other trees less seriously damaged at this time showed degrees of injury ranging from wilting of the leaves or partial defoliation to death of twigs and smaller branches. The fruit was undersize, poorly colored, delayed in maturity, and in some varieties affected by drought spot, watercore, or sun scald.³

EFFECTS OBSERVED IN 1931

Many trees which entered the dormant period apparently sound in 1930 showed injury the following summer. It is probable that deep roots suffered from the continuance of the drought after dormancy of the tops in 1930, as the subsoil remained dry in many orchards until spring. Some root injury from freezing might have occurred, as the temperature dropped to six degree on November 29 (the lowest November temperature ever recorded at Martinsburg), and to 7 degrees on November 30. The soil at this time was still very dry and there was no protective cover of snow. Subsequent winter temperatures were unusually mild. In the spring and summer of 1931 rainfall 5.25 inches above normal favored the recovery of the trees.

Injury as observed in 1931 was characterized by death of entire trees, death of all but one or several branches, death of twigs, persistent dormancy of terminals, from 6 to 8 weeks delayed blossoming of a few spurs, rosette, early defoliation, small fruit, poor color, drought spot, and watercore. Trees showing death of portions of the tops usually revealed death of roots from $1/16$ to $1/4$ or more inches in diameter. In severe cases main roots up to 4 inches in diameter were dead, the tops then having little or no life in them. Most of the data presented are based on observations made in 1931, the effects of the drought having been more easily determined then than during the drought year.

Trees weakened through girdling by mice or rabbits; trees (most commonly Grimes Golden) infected with collar rot; and trees in a badly crowded condition or on shallow or impoverished soil incapable of maintaining tree vigor, were the first and most severely affected.

EFFECTS OF SOIL DEPTH AND OTHER FACTORS

It is of interest to compare the growing-season rainfall of 13.9 inches, and the annual rainfall of 21.43 inches at Martinsburg in 1930, with that of certain regions in which the normal rainfall is at least equally low (Table I). At Kalmar, Sweden, in one of the most productive apple districts in the country, the normal precipitation for the 8 months' growing season is 11.3 inches. The average annual precipitation is 15.4 inches. In summers of rainfall considerably below the normal at Kalmar no unfavorable effects have been

³By the time the drought had become acute the dry, compact condition of the soil made soil moisture determinations and the investigation of root injury difficult. Root conditions were observed the following summer.

observed. With the usual low summer temperatures the transpiration rate and loss of soil moisture by direct evaporation are, of course, very much lower than in West Virginia in 1930.

At Moscow, Idaho, the average precipitation for the growing season is 11.6 inches, and the average for the year is 22.07 inches. Average and maximum summer temperatures are below those of Martinsburg in 1930. In the Experiment Station orchard at Moscow, located on a deep soil of good physical character, moderately large crops of apples of good size and good color development are produced in average seasons without irrigation. In years when the summer rainfall has been from 3 to 4 inches below normal the fruit has failed to attain good size and color, but there has been no injury to the trees from lack of moisture.

At The Dalles, Oregon, where the average growing-season rainfall is only 5.61 inches, but where the soil is very deep, stone fruits are successfully grown without irrigation. Apple trees, however, have suffered seriously from drought; probably for the most part during years of subnormal precipitation. Summer temperatures are below those of Martinsburg.

These comparisons indicate that the damage suffered by fruit trees in West Virginia in 1930 is not entirely attributable to insufficient rainfall. Other factors are at least equally responsible, such as (1) the atmospheric conditions under which the summer rains occurred—conditions favoring rapid water loss by evaporation and transpiration; (2) the lack of adaptation of the trees of this region to low rainfall conditions; and (3) the lack of soil depth and soil moisture-holding capacity of many West Virginia orchards. It is known that the depth and character of the root systems of fruit trees, and the proportion of roots to tops, are influenced by the normal water supply in such a way that a much reduced supply for one season, while perhaps of sufficient quantity for trees long adapted to a low supply, may not be sufficient for trees accustomed to much more. This was no doubt an important factor in the injury experienced here in 1930.

It is notable, however, that on deep soils in good physical condition, capable of storing a large reserve of moisture from late fall and winter precipitation, trees of all varieties withstood the drought without injury. In some instances heavy crops of fruit of good size and good color were matured. The drought has thus emphasized the lack of soil moisture-holding capacity as one of the greatest inherent weaknesses of orchards in this region.

The orchards suffering most from this are on high ground or on hillsides where erosion has worn the soil thin; on shallow shales; and on limestone soils made shallow in places by the outcropping of rock. A few instances of injury were observed on deep, low-lying soils with a high water-table; and in similar locations without a high water-table in which, however, in normal years abundant surface moisture from drainage of the higher surroundings had encouraged shallow rooting. In the latter locations the trees were usually larger

than those on adjacent, higher ground, indicating favorable growing conditions in previous years; but they suffered greater injury from the drought. When the trees in one such location were removed late in 1931 the root systems were observed to be very shallow, and very small in proportion to the tops of the trees.

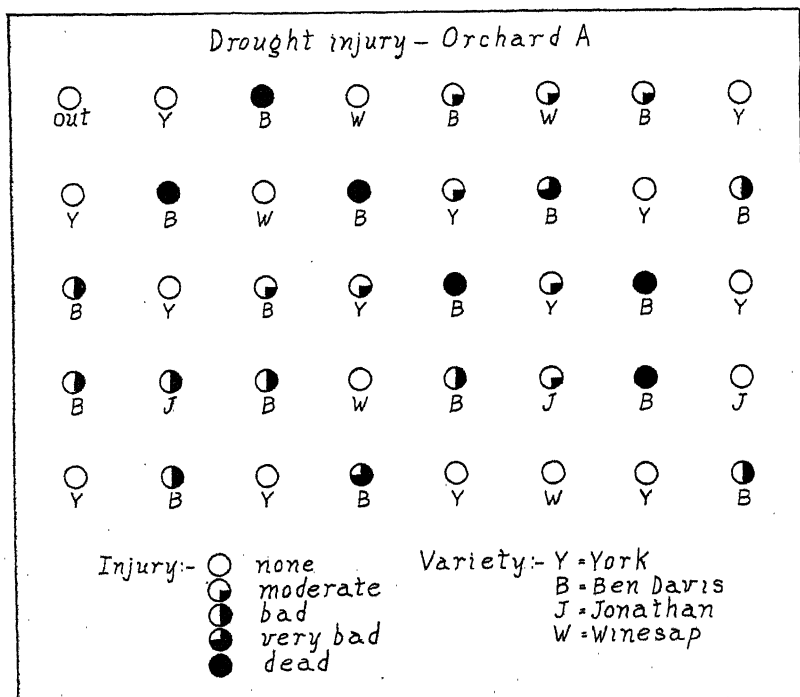


FIG. 1. Drought injury in an interplanted orchard.

VARIETAL SUSCEPTIBILITY

Of the varieties commonly grown in West Virginia, Ben Davis and York Imperial represented widely separated extremes in susceptibility to drought injury, the former proving very susceptible and the latter highly resistant. Ben Davis set a heavy crop in 1930 while most of the York trees were in their off year. Size of crop, however, seems to have had relatively little effect on the damage suffered by the tree. An occasional bearing tree or bearing block of York showed no more injury than nearby fruitless trees, while Ben Davis trees not yet of bearing age suffered as much in relation to other varieties as did trees with crops.

Orchard A (Fig. 1) shows the relative amounts of injury suffered by several interplanted varieties near Berkeley Springs, as observed

in the summer of 1931. The degrees of injury are classified into five groups as listed below:

1. No apparent injury.
2. Moderately injured: foliage rather sparse, leaves smaller than normal, sometimes a little rosette, no dead twigs.
3. Badly injured: foliage sparse, leaves small, sometimes rosette, scattered dead twigs.
4. Very badly injured: foliage very sparse, leaves small, rosette quite general, numerous dead twigs and often large branches dead.
5. Tree dead or beyond recovery, *i.e.*, life remaining in only a few branches or in trunk.

While the above grouping is necessarily arbitrary and subject to some error in classification, it serves the present purpose of showing wide differences on a comparative basis. The same classification has been used throughout.

TABLE II—VARIETAL DIFFERENCES IN DROUGHT INJURY

Variety	Orchard	No. of Trees	Trees Showing Following Degrees of Injury (Per cent)				
			None	Moderate	Bad	Very Bad	Dead
York.....	A	24	87	8	5	0	0
Jonathan.....	A	26	35	54	8	3	0
Winesap.....	A	11	9	55	18	18	0
Gano.....	A	29	17	21	24	38	0
York.....	B	21	81	19	0	0	0
Jonathan.....	B	98	61	28	11	0	0
Stayman.....	B	47	16	28	30	26	0

The soil in orchard A* is a deep, compact shale low in organic matter. The trees were 19 years old in 1931. The planting distances are 25x25 feet, the trees showing the effects of crowding. All varieties except Ben Davis set moderate crops in 1931. All varieties are reported to have had moderate crops in 1930, but this is questionable with respect to most of the Yorks.

Another portion of orchard A (Table II) shows comparative injuries to interplanted York, Gano, Winesap, and Jonathan.

Orchard B (Table II), on a stony loam soil near Hedgesville, shows the extent of injury to York, Jonathan, and Stayman planted in alternate rows on nearly level ground. This orchard was 18 years old in 1931. With planting distances 30x40 feet the trees are not crowding. Jonathan and Stayman set heavy crops in both 1930 and 1931. York was in its off year in 1930 and set heavily in 1931.

The nature of the injury observed varied with different varieties. Injury to Ben Davis and Gano, for instance, was characterized by defoliation and by killing of all or parts of the tree. Size and color

*Orchards A, B, and C were all in sod in 1930 and 1931.

TABLE III—GROWTH DEPRESSION OF DELICIOUS APPLE TREES VARIOUSLY INJURED BY DROUGHT

Extent of Injury	No. Trees	Average of 10 Terminal Growths per Tree for 10 Trees (Inches)			Terminal Growth Depression Based on 1929 Growth as Normal (Per cent)		Trunk Circumference One Foot above Ground (Inches)		Per cent Increase	Depression of Trunk Growth in 1931 (Uninjured Trees as Normal) (Per cent)
		1929	1930	1931	1930	1931	1930	1931		
No apparent injury	10	12.70	8.05	7.36	37	42	32.0	34.2	6.6	0
Moderately injured	10	12.64	6.77	1.73	46	86	26.8	28.4	6.2	6
Badly injured	10	11.48	5.48	.79	52	93	25.6	26.7	4.5	32
Very badly injured	10	11.77	4.99	.62	58	95	23.7	24.3	2.7	60
Dead or nearly so	10	10.91	3.85	.12	65	99	19.5	19.3	—8	100

of fruit suffered less in proportion to tree injury than in Stayman, in which lack of size and poor color of the fruit, and rosette, were characteristic, but in which there was relatively little killing of parts of the tree.

As nearly as the varieties observed can be classified at present Ben Davis proved the most susceptible to injury, with Gano, Grimes Golden, and Stayman ranking next in the order named. In the rating of Grimes Golden there must be considered the effect of collar rot, which is widespread on this variety. Of the resistant varieties York Imperial was the most outstanding, with Jonathan, Winesap, and Arkansas (Black Twig) ranking next. Of other varieties less closely observed Yellow Transparent, Duchess, and Delicious seemed high in resistance; and Rome Beauty and Summer Rambo relatively low.

EFFECTS ON TREE GROWTH

Orchard C is a solid planting of Delicious, 19 years old, located at Kearneysville on Hagerstown clay loam soil. Varying soil depth due to the presence of limestone rock at intervals throughout the orchard resulted in various degrees of injury to these trees. Trunk circumference measurements and notes on the condition of the trees were taken in early September, 1930, and in early October, 1931. As poor pollination in this orchard has prevented the set of more than a scattered crop of fruit, the size of crop has not been a factor in the growth behavior of these trees.

It is apparent from the data presented in Table III that the depression of terminal growth was one of the earliest responses to the drought, the checking of terminal growth having been almost as marked in trees suffering only moderate injury as in trees very badly affected. In all trees the effect on terminal growth was greater the year following the drought than during the drought year. This is readily understood when we consider that the drought did not become acute in 1930 until the most active growth of the trees, which normally occurs early in the season, had taken place. The following spring the carry-over effects of the drought, in the nature of impaired root systems, deficient food storage, and in some orchards low moisture content of the subsoil, were most keenly felt at the beginning of the growth period.

Terminal growth in 1931 was checked more than trunk growth. There is, in fact, no indication of retarded trunk circumference increase in the trees not visibly injured, the trunk growth of these trees in 1931 having been greater than their average annual growth prior to 1931. It is interesting to note, further, that the size of trunk decreases with increasing degrees of injury, the injured trees evidently having felt the effects of unfavorable growing conditions for many years.

Lowering Apple Orchard Cover Crop Costs

By FRED W. HOFMANN, *Virginia Agricultural Experiment Station, Blacksburg, Va.*

VIRGINIA apple growers are becoming increasingly interested in the value of soil organic matter. Most of them are using some form of cover cropping such as the sowing of rye with vetch in the fall to be turned under in spring followed with the planting of cow peas or soy beans in June. Excellent results with increased fruit yields have been secured by this program.

In 1927 a portion of the general experimental orchard of the Virginia Agricultural Experiment Station at Blacksburg, which is maintained under a system of annual cultivation until June, was observed to have accumulated a noticeable amount of organic material over a period of 16 years. This system of cultivation permitted native volunteer growth to develop sufficiently to add an appreciable amount of organic material to the soil each year. As a result the soil became much darker and of much better tilth than the soils in the clean cultivation plats. These observations led to a study of the value of utilizing volunteer native and more or less established perennial growth for a less expensive method of securing a sufficient abundance of organic matter in the orchard soil.

To conduct experiments with this study in mind an orchard plat was selected which had in the beginning a very poor heavy clay soil just barely able to grow a native cover. This plat had been set to apple trees in 1915 and kept in partial cultivation until 1926 after which it was allowed to grow up to a general assortment of volunteer plants. Finally a sod was formed, made up mostly of orchard grass, Kentucky blue grass, and hawkweed.

In the spring of 1930 the rows of this plat were plowed in one direction only. Later in the spring they were disked and then disturbed no more that season. During the spring and summer the torn pieces of sod grew more vigorously than ever, and in spite of the severe 1929 and 1930 drought the broken-up rows were filled with a luxuriant growth composed of orchard grass, Kentucky blue grass, and hawkweed. This growth was in most noticeable contrast to the less vigorous growth in the unplowed strips.

In the spring of 1931 or the next season, rows were plowed at right angles to those plowed the last season. It is planned to keep up this system of plowing in one direction one year and at right angles the following year over several seasons. The extent to which a new sod develops after the turning under and the general tearing up, gives it considerable promise as a less expensive method of securing an abundance of organic matter. The trees were not plowed on all sides in the one season, first to avoid the possibility of severe root dis-

turbance, and second, in order that some sod may be left in reserve each season to spread from the unplowed into the plowed strips.

With some modification a system of this general principle could also be used on the steeper slopes which generally preclude cultivation without disastrous soil washing. On the steeper slopes a plan of alternate strip plowing could be carried out whereby every other row running across the prevailing slope or along the general contour would be plowed one season to be allowed to grow back into a volunteer sod.

This utilization of volunteer sodding and other perennial growth may have considerable merit. Sods on the whole provide large amounts of desirable organic materials. The general objection to sod is its competitive tendency and the encouragement it gives to the harboring of mice, after it has become established in the orchard for several years. The intermittent and alternate plowing herein suggested not only removes these objectionable features but provides a means of securing an abundance of desirable organic material in a relatively inexpensive way.

Some Changes in the Homemade Paddle Apple Washer

By FRED W. HOFMANN, *Virginia Agricultural Experiment Station, Blacksburg, Va.*

AS far as the removal of arsenical residue from the fruit is concerned the homemade apple washer designed by the United States Department of Agriculture has proved to be a very efficient device at the Virginia Agricultural Experiment Station considering the amount invested. There are some changes that would be desirable such as provision for a more thorough rinsing with clear water and a more thorough removal of moisture.

In some trials at this station with several makeshifts set up by the writer, improvements in these phases seem to be quite possible with relatively little expense. Very satisfactory final rinsing was secured from a half-inch pipe drilled with fine holes 2 inches apart across its length and connected so that it was suspended directly over the second slat of the conveyor emerging from the rinse tank. Excellent rinsing was also accomplished with two 4-nozzle clusters. The fine mist of clear water coming down upon the apples as they passed under these eight nozzles gave them a thorough final rinsing. Both of these devices not only provide for a thorough final rinsing but help to keep a fresher supply of water in the rinse tank.

Following the washing and thorough rinsing in clear water it is desirable to remove as much moisture as possible with the least amount of delay before packing the fruit. It has been found that a

very material amount of this moisture can be removed with a relatively simple and inexpensive set of devices.

Three rubber sponge knee pads secured from one of the popular novelty shops at a cost of 25 cents each were fastened together across their lengths with two $\frac{1}{2} \times 1$ inch wooden strips, after which they were suspended securely across the conveyor chute directly over its last slat. The rubber sponge was then cut into ribbons about an inch wide and four long. As the apples are carried along on the conveyor they are squeezed through these sponge rubber ribbons with the result that they are wiped off very effectively. It would be well to have one of these devices over the last slat of the conveyor coming from the acid tank as well as the one coming from the rinse tank. This will help to reduce the amount of acid moisture that would otherwise come over with the apples.

These provisions for moisture removal may be supplemented further by the construction of a delivery chute with open or slatted flooring which would permit any drippings that are carried over, to fall through. With a solid flooring these drippings will drain down into the receiving container with the apples. Further removal of moisture from the fruit and elimination of the drippings can be effected by fastening under the delivery chute several strips on which 1-inch cubes of sponge rubber have been tacked at the correct intervals to protrude slightly between the slats of the delivery chute. These sponge rubber equipped slats can be distributed about 10 inches apart horizontally across the bottom of the chute. As the apples roll down the chute they strike these rubber sponge cubes which will cause an appreciable amount of moisture to be rubbed off from the fruit. For a 4-foot chute, about two sponge rubber pads will be sufficient.

The Effects of Humidity and Temperature Upon the Wetting of Peach Shoots

By W. A. RUTH and G. V. FALKENBERG, *University of Illinois, Urbana, Ill.*

IN the winter of 1921-22, the senior author observed that the younger and smoother surfaces of apple branches wet more easily in the orchard than in the laboratory. A continuous covering of water might be left on a last year's shoot by dipping or spraying it in the orchard, but if the shoot were sprayed or dipped after it had stood 30 minutes or more in the laboratory, parts of the smooth surface would be left dry. On older smooth surfaces the difference was not so marked. Pubescent or wrinkled surfaces wet easily both outdoors and in the laboratory. Sprays without a "spreader" or "wetting agent" acted like water.

Because it was found in the laboratory that greasy apples, which wet with difficulty, would retain a more nearly uniform and continuous film if the hot radiators were sprayed first, it seemed likely that relative humidity, rather than temperature, was responsible for the difference. It was not necessary to vaporize enough water to form a visible deposit. The fact that the amount of invisible water on surfaces can be considerable had been demonstrated to the senior author in the course of transpiration work with cobalt chloride paper. When the relative humidity in the greenhouse was raised by wetting down the pipes, the leaves of a notebook, which were highly calendared and presumably not especially attractive to water, would "transpire" as rapidly as the leaves of the plants, and much more rapidly than the plants transpired at other times. No steam had reached the notebook, and the water on the surface could not be seen or felt.

The possible practical significance of the difference in wetting indoors and outdoors lay in the fact that wetting outdoors might vary from time to time according to atmospheric conditions. Although it seemed very likely that wetting in the orchard would vary with the relative humidity, such a correlation had not been recorded. In 1931 this relationship, as well as the relationship to temperature, was studied both outdoors and in the laboratory.

MATERIALS AND METHODS

Moderately vigorous shoots of last season's growth from outer branches of 3-year-old peach trees were used, because the smooth internodal surface is sometimes hard and at other times easy to wet, and because a large number of comparatively uniform shoots were available.

Since time is a factor in wetting, the shoots were immersed in the liquid for approximately 1 second. They were withdrawn gently and,

as far as it could be accomplished by hand, at an equal and even rate. This precaution was desirable because the amount of liquid adhering, and probably its continuity, would depend to some extent upon the rate of removal from the liquid (5). Only the experiments in which distilled water was used will be reported at this time, and the report will be confined to qualitative tests.

TABLE I.—WETTING SECURED BY DIPPING PEACH SHOOTS IN WATER ON DIFFERENT DAYS AND UNDER DIFFERENT CONDITIONS OF RELATIVE HUMIDITY, TEMPERATURE, AND SUNSHINE

Date	Temperature (Degrees F)	Wetting in Orchard		Relative Humidity	Sunshine
		Good	Poor		
2-16	43	+		70	—
2-17	45	+		79	—
2-19	40	+		80	—
2-21	42	+		66	+ —
2-23	44	+		74	—
2-24	37	+		83	+
3-9	36	+		73	+
3-10	33	+		77	+
3-11	32	+		66	+
3-12	47	+		58	+
3-14	37	+		91	—
3-31	44	+		65	+ —
4-11	62	+		28	+
4-14	74		+	56	+
4-16	76		+	55	+
4-18	70		+	26	+
4-21	49	+		77	—
4-23	48	+		60	—
4-25	53	+		74	—
4-27	42	+		55	—
4-28	59	+		41	+
4-30	63	+		38	+
5-2	62		+	48	+
5-4	69		+	36	+
5-5	76		+	37	+
5-7	51	+		63	—
5-9	51	+		75	—
5-12	59	+		73	—

Wetting was described as soon as the shoots were removed from the water. This was not quite accurate because a more or less prolonged recession usually occurred. Wetting was said to be good when the entire surface was covered. When wetting was intermediate dry areas were left and the outlines of the liquid were irregular. In very poor wetting the liquid collected at once into drops, which were almost spherical in the most extreme cases.

The surfaces to be tested were not touched with the hands and were not allowed to come into contact with other surfaces.

Tests in the orchard: Dipping in the orchard was started February 16, and continued until May 12. The results and the temperatures, relative humidities, and the presence or absence of sunshine, which were observed when the shoots were dipped, are recorded in Table I.

One can summarize the data as follows: the previous years' shoots invariably wet well in February and March, but in April and May there were alternate periods of good and poor wetting.

During periods of good wetting the relative humidity was usually higher, ranging from 38 to 91 and averaging 67, than when wetting was poor, when it ranged from 26 to 56 and averaged 43.

When the shoots wet well the temperature was usually lower than when they wet poorly. During periods of good wetting the temperatures ranged from 32 to 63 degrees F. and averaged 46 degrees F.; during periods of poor wetting the temperature ranged from 62 to 76 degrees F., and averaged 71 degrees F.

When the shoots failed to wet easily the sun was always shining; when they wet poorly it was sunshiny (9 times) about as often as it was not (12 times).

Effect of warming shoots in an oven: On days when wetting in the orchard was good, shoots were kept in an electric oven in the laboratory at 104 degrees F. for $\frac{1}{2}$, 1, 2, 3, and up to 30 minutes; at 169 degrees F. for 1, 2, 3, 4, and 5 minutes; and at 194 degrees F. for $\frac{1}{2}$, 1, 2, and 3 minutes, after which they were immediately dipped in distilled water. Shoots heated to the higher temperatures for more than 30 seconds were warm to the touch, and shoots exposed to 169 degrees F. for 5 minutes or to 194 degrees F. for 3 minutes were greasy.

Exposure to 104 degrees F. for 2 minutes or more resulted in poorer wetting. When the shoots which had been treated for 2 minutes at this temperature were removed from the water a few small dry areas appeared at once. The number and size of the dry areas increased roughly with the duration of heating; the water did not form spherical or hemispherical drops, however, even on shoots heated for 30 minutes.

Exposure to 169 degrees F. for 1 minute was sufficient to result in dry areas at the bases of the shoots; the size and number of these areas increased with increasing exposure, and, on shoots which had been heated for 4 or 5 minutes, the water took the form of drops.

Exposure to 194 degrees F. for 1 minute was sufficient to result in the formation of drops, and on shoots exposed for 3 minutes very little of the surface was wet.

In all cases where an effect was produced by heating, the wet areas decreased in size after the shoots were taken from the water, the rate and extent of recession varying with the temperature and duration of heating.

Effect of exposing shoots to steam: In this experiment shoots were brought into the laboratory when wetting in the orchard was poor. They were hung near the top of a bell jar, into which steam could be led at the bottom through a tube which could be connected with the source of steam. The steam was made by boiling water gently in a flask over a laboratory burner. The hole in the top of the bell jar was left open so that the steam, which was not directed toward the

shoots, would reach the top more easily. A thermometer was hung with the shoots. Immediately after steaming, the shoots were removed and dipped.

It was found repeatedly that when steam was passed in for 15 to 60 seconds wetting was made easier, but when it was passed in for 2 minutes wetting became more difficult. The observed temperature in the latter case never was above 92 degrees F., but the shoots were warm to the touch.

Effect of exposing shoots to laboratory and cold storage atmospheres: The effect of exposure in the laboratory and cold storage was tested on days when wetting in the orchard was easy, and on other days when it was difficult. On days when shoots wet easily in the orchard they usually wet with increasing difficulty with increasing exposure to the laboratory atmosphere. There was, however, considerable variation between tests. In some of the tests an effect was produced in 15 minutes, but in other tests no effect was observed after a 2-hour exposure. In the following test the first effect was observed in 30 minutes. The progressive effect is typical.

On April 21, 50 shoots were cut from the trees and laid on the laboratory bench. The outside temperature was 48 degrees F., the relative humidity was 60, and the day was cloudy. The laboratory temperature was 75 degrees F, and the relative humidity was 47. At 15-minute intervals 10 shoots were removed from the bench and dipped in distilled water. On the first lot, dipped 15 minutes after the shoots were brought in, wetting seemed to be as easy as it had been in the orchard; that is, a continuous cover was produced. On shoots dipped after 30 minutes' exposure, a few dry areas appeared; the size of the dry areas seemed to be larger on shoots dipped after 45 minutes, and was certainly larger on shoots dipped after 1 hour. The dry areas on shoots exposed for 2 hours seemed to be still larger, but the spray did not collect into drops, even after an exposure of this duration.

No change was observed within 2 hours in the cold storage, where the relative humidity was about 85, and the temperature between 33 and 35 degrees F. No observations were made after 2 hours.

Effect of high and low relative humidities at high and low temperatures: Shoots were brought in from the orchard and placed in desiccators containing calcium chloride or water. Twelve shoots were used in each desiccator in every test. One of each was kept at room temperature (70 to 80 degrees F.) and one of each in the cold storage (at 33 to 35 degrees F.) Tests were made on days when wetting was good, and on other days when it was poor. Shoots were removed and dipped at 15-minute intervals.

The results as shown in Table II are consistent. Wetting was made difficult by exposure in the desiccators to low humidities at both temperatures, while it was promoted, unless already very easy, by exposure to high humidity at either temperature. In this experiment humidity was plainly the more important factor. Temperature pos-

sibly hastened the effect; visible results were produced within 30 minutes at the higher temperature, but only after longer exposures at the lower temperature.

TABLE II—EFFECT OF HIGH AND LOW HUMIDITY AT 70 TO 80 DEGREES F AND 33 TO 35 DEGREES F ON WETTING THE SMOOTH SURFACES OF PEACH SHOOTS

Temperature (Degrees F.)	Time in Desic- cators (Minutes)	Degree of Wetting in the Orchard	Wetting of Shoots in Laboratory after Treatment in Dry and Moist Desic- cators
Humidity Low (Dry)			
70-80	15	Good	Good—continuous film
70-80	30	Good	Some dry areas
70-80	30	Poor	Poor—same as in orchard
70-80	120	Poor	Poor—same as in orchard
33-35	15	Good	Good
33-35	120	Good	Poor
33-35	30	Poor	Poor
33-35	120	Poor	Very poor—water in drops
Humidity High (Moist)			
70-80	15	Good	Good
70-80	120	Good	Good
70-80	15	Poor	Good—better than in orchard
70-80	120	Poor	Good
33-35	15	Good	Good
33-35	120	Good	Good
33-35	15	Poor	Poor
33-35	120	Poor	Good

Discussion: The orchard and laboratory tests show that, except at the higher temperatures, a high relative humidity promotes wetting. Temperatures above 90 to 100 degrees F. were unfavorable even at high humidities. It is, therefore, possible for high temperatures to act unfavorably either directly, or by decreasing the relative humidity, or both directly and indirectly.

According to the theory of wetting which Quincke (2, 3) developed in 1859 and 1877 from his own and still earlier observations, complete wetting, which would be evidenced by spreading, would not result from the adsorption of water. Spreading, as he and other investigators have concluded, (1) calls for the direct contact of liquid and solid, which an adsorbed film of the liquid prevents. According to Quincke, (3), the contact angle of a drop of water upon carefully purified or fresh solid surfaces always increases with the time elapsing after their purification or formation, because of the condensation upon them of gases or vapors from the atmosphere. Without this film the angle is zero and the liquid spreads.

In these experiments spreading was not secured by an exposure to high humidities, and wetting, although it was improved, was usually imperfect, as shown by the prolonged recession of the water on the dipped areas. The improvement in wetting seems, nevertheless, to have been due to the substitution of water for air on the surface of the shoots. It may have been due to the condensation of more than the thin layer of water adsorbed, or to the retention of so little air that the air left could be dissolved by the water. The steps involved are discussed by Quincke in the early publications already cited.

At higher temperatures the relationships between the various surface attractions concerned in wetting seem, in this case, to be shifted in a way unfavorable to wetting.

Significant differences in control or unexplained differences in the effects of sprays may result from applying sprays under different atmospheric conditions, because the continuity of the cover would differ. This possibility applies to surfaces other than the one upon which the tests were made and to liquids other than the one applied in this experiment.

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Summer Oil Sprays for Late Brood Codling-Moth

By H. G. SWARTWOUT, *University of Missouri, Columbia, Mo.*

CONFRONTED with the problem of arsenical residue, fruit growers have become interested in possible substitutes for lead arsenate and other arsenicals. The Missouri Agricultural Experiment Station has been working with a number of possible substitutes among which have been the so-called "white oil" emulsions.

In 1930 a white oil emulsion of medium viscosity (80-85 seconds Saybolt) was used in the second brood codling-moth sprays across a plot of seven varieties of apples, namely, Jonathan, Grimes, Delicious, York, Winesap, Gano, and Ingram. The remainder of the trees in the planting received arsenate of lead 1 to 50 the same day that the oil was applied except one tree of each variety which was to serve as a second brood check. The early season sprays were the same for all trees including the check and consisted of lime-sulphur $1\frac{1}{4}$ to 50 at the cluster bud period, lime-sulphur $1\frac{1}{4}$ to 50 plus 1 pound arsenate of lead at the calyx period, first cover and second cover at 2-week intervals, and lead arsenate alone 1 to 50, June 5 and June 19. Three applications of the summer oil using approximately 1.3 per cent oil (2 per cent emulsion) and lead arsenate 1 to 50 were made for second brood codling moth July 3, 15, and 22.

FOLIAGE AND FRUIT INJURY

Foliage injury and spotting of the fruit appeared on some of the oil sprayed trees, the severity of the injury varying greatly with the variety. Such injury may be briefly summarized as follows:

<i>Foliage Injury</i>		<i>Fruit Spotting</i>	
Grimes, severe	York, trace	Grimes, severe	
Winesap, moderate	Ingram, trace	Jonathan, moderate	
Jonathan, fairly light		Other varieties, mostly none or an occasional slight discoloration.	
Delicious, fairly light			
Ben Davis, light			

Foliage injury was considered serious only on Grimes. While light to moderate amounts of burning appeared on the other varieties, it was no more than often occurs with liquid lime-sulphur and less severe than injury that sometimes follows the use of lime-sulphur.

Fruit spotting was quite severe on Grimes, most of the fruit being so conspicuously marked as to reduce its market value. While fruit spotting was less severe on Jonathan and less evident, the percentage that would be reduced in grade was commercially excessive. On other varieties spotting could be detected only on close examination, and it was not considered sufficient to affect the market value of the fruit.

The sprays were applied during a period of high temperatures, the mean maximum temperature for the month of July being nearly 94

degrees F. The abnormally hot and dry weather may have given more injury than would ordinarily have occurred.

Three commercial summer oil emulsions, one of medium heavy oil (about 95–100 seconds Saybolt), one of medium oil (80–85 seconds Saybolt), and one of light medium oil (60–65 seconds Saybolt) were used in 1930. All emulsions were diluted to give approximately 1.3 per cent actual oil. The oil, lead arsenate, and second brood codling-moth check plots all received the same early season sprays, consisting of dry lime-sulphur 4 to 50 at the cluster bud period, dry lime-sulphur 4 to 50, and lead arsenate $1\frac{1}{2}$ to 50 at the calyx, first, and second cover sprays, and lead arsenate alone 1 to 50 at the third cover spray on June 15. The second brood codling-moth sprays of oil and lead arsenate were applied on July 13, July 23, and August 13.

TABLE I—COMPARATIVE FRUIT SPOTTING WITH SUMMER OILS

Oil	Percentage Severe Spotting of Fruit		Percentage Light Spotting of Fruit					
	Grimes	Jonathan	Grimes	Jonathan	Delicious	Gano	York	Ingram
Medium.....	31	26	43	27	11	27	8	38
Light medium...	8	1	39	16	0	16	5	5
Medium heavy...	33	5	46	24	1	24	29	13

Oil injury was evident again, varying with the variety and oil used. Foliage injury was severe on Grimes, most of the leaves being badly burned with some dropping. The injury was the more severe with the medium and medium heavy oils, injury with the light medium oil being markedly less. Other varieties showed light to moderate amounts of injury with the medium and medium heavy oils and very little injury with the light medium grade.

The fruit was left on as late as feasible to get as much color as possible. Counts were made after harvesting and the percentage of apples showing oil spots determined. Two classes of injury were made, namely, severe injury, which was great enough to affect the market value of the fruit; and light injury, which was barely perceptible and which probably would not affect grade on market value. The results are presented in Table I.

Grimes and Jonathan were the only varieties used which showed heavy or noticeable spotting of the fruit. The spotting designated as light consisted of only an occasional spot or several spots so light as to be hardly perceptible. Fruit spotting was appreciably less with the light medium oil than with the medium and medium heavy oils.

Trees sprayed with oil in 1930 were sprayed with the same oil (80–85 seconds Saybolt) in 1931, and spraying will be continued to note any physiological disturbances in growth and fruiting caused by continued use of summer oils. So far no effect has been observed. It might be mentioned, however, that in a commercial orchard where one of the summer oils was used this past season on Jonathan, it was observed that the foliage remained greener and the apples held better

where the oil was applied than where lead arsenate was used. Because of the heavy drop of Jonathans this was deemed an advantage.

TABLE II—SECOND BROOD CODLING MOTH CONTROL WITH SUMMER OIL AND LEAD ARSENATE

Variety and Date of Harvest	Number of Worms and Stings per 100 Fruits		
	1.3 Per cent Oil (80–85 Seconds Saybolt) 3 Late Sprays	Lead Arsenate 1–50 3 Late Sprays	Check No Sprays After June 19
Jonathan—August 22.....	4.3	3.6	14.8
Grimes—September 10.....	11.8	12.6	—
Delicious—September 13....	13.1	26.8	57.9
Winesap—September 27....	23.9	28.1	33.3
Gano—September 27.....	23.8	37.4	70.4
Ingram—September 27.....	30.4	38.8	77.5

CODLING-MOTH CONTROL.

The failure of codling-moth to be a problem in 1931 in the orchard in which the oils were used prevented the securing of definite information on control. Less than 5 per cent of codling-moth injury was found on most trees which received no spray all season. The results for 1930 are presented in Table II.

The summer oils gave a control of second brood codling-moth essentially equivalent to the lead arsenate. The number of stings were less in the oil-sprayed plots. Owing to the appearance of many late larvae, the number of injuries per 100 fruits is somewhat high for the later harvested varieties. A later spray in August probably would have reduced the number of injuries considerably.

TABLE III—ARSENICAL RESIDUE ON APPLES IN 1930

Treatment	Arsenic Trioxide (Grains per Pound)					
	Jonathan	Grimes	Delicious	Gano	Winesap	Ingram
Lead arsenate—selected...	.024	.027	.025	.025	.022	.021
Lead arsenate—tableapples	.015	.019	.023	.009	.012	.008
Oil—selected.....	.013	.014	.011	.009	.007	.008
Oil—table apples.....	.015	.009	.010	.009	.007	.007

ARSENICAL RESIDUE

The amount of arsenical residue on the fruit was determined for the different varieties in the various plots. Apples marked "selected" were chosen which showed the most stain or residue and were carefully handled to avoid loss of any of the spray material. Those marked "table apples" were picked and handled in the ordinary manner. Fruit which showed the most stain were chosen for analysis as they came over the packing table. The results of analysis for 1930 are shown in Table III.

The substitution of oil sprays for lead arsenate in the late applications considerably reduced the residue of arsenic on the fruit at time

of harvest, the residue being in most cases near or below the tolerance of .01 grains. The extremely dry year of 1930 probably resulted in a somewhat higher residue than would ordinarily occur.

TABLE IV—ARSENICAL RESIDUE ON APPLES IN 1931

Variety	Arsenic Trioxide (Grains per Pound)		
	(Oil medium)	Lead Arsenate	Check No Sprays After July 1
Jonathan	.007	.019	.009
		.040	.008
		.020	.009
			.004
Grimes	.010 .008	.040	.003
		.020	.004
		.021	.006
Delicious	.008	.019	.013
		.021	.005
			.006
York	.008	.035	.007
Gano	.010	.020	.005
Winesap	.011	.020	.004
Ingram	.009	.021	.004

The results of residue analysis for 1931 are presented in Table IV. Only carefully handled apples selected from the trees and which showed the greatest residue were used. Also, the apples were chosen for the minimum size of $2\frac{1}{2}$ inches except Winesap and Ingram which were $2\frac{1}{4}$ inches. By using small apples it was felt that the residue would be the maximum that could be expected on these apples if packed.

All check tree samples except one, and all oil samples except one, show .01 grains or less of arsenic as arsenic trioxide. The late sprayed lead arsenate samples were all high, showing about .02 grains or more of arsenical residue.

CONCLUSIONS

The results presented here together with other results and observations where growers have used oil indicate that the heavier summer oils compare favorably with lead arsenate in controlling the later broods of codling-moth and that in a year of normal or nearly normal rainfall and without a heavy early season spraying program the residue of arsenic might be expected to be within .01 grains. However, information to date shows considerable risk of immediate injury on some varieties. No effect from two successive seasons' use of summer oils has been noted.

The Evolution of the Horticulturist

(PRESIDENTIAL ADDRESS)

By T. H. McHATTON, *State College of Agriculture, Athens, Ga.*

IT was at the very dawn of our modern era, if we accept the historian's division of time, that Columella wrote, "I cannot enough wonder why they who desire to learn eloquence are so nice in their choice of an orator, whose eloquence they may imitate; and they who search after knowledge of surveying and numbers look out for a master of the art they delight in; and they who are desirous of some skill in dancing and music are exceedingly scrupulous in their choice of one to modulate their voices or to regulate the motions of their bodies; also they who have a mind to build send for architects, masons and carpenters; and they who resolve to send ships to sea send for skillful pilots; they who make preparations for war call for men of war; and everyone sends for a person from the society and assembly of the wise to form his mind and instruct him in the precepts of virtue; but husbandry alone, which, without all doubt, is next to and, as it were, near akin to wisdom, is in want of both masters and scholars I, myself, have seen schools of professors of rhetoric, of geometry and of music and academies for the most contemptible of vices; also for head dressers and hair trimmers, but of agriculture, I have never known any that profess themselves either teachers or students." And again he says, after describing the general attitude of the Romans toward agriculture, "Nor is there any wonder that the vulgar opinion is now publicly entertained that husbandry is a sordid employment and that it is a business that does not want the instruction of a master. But as for myself, when I consider and review either the greatness of the whole thing, resembling some vastly extended body, or the number of its parts, as so many members in particular, I am afraid, lest my last day should surprise me before I can acquaint myself with the whole of rural discipline."

One who peruses his voluminous writings can but marvel at the keen insight he displayed concerning things agricultural and horticultural. So true was his statement that rural culture was looked down upon that this history of the very heart of Rome, this economic treatise of the times, has been pigeon-holed and forgotten by the very ones who should have used its gems of living philosophy in expounding the humanities that they so loudly preach are necessary in cultivating the human mind. Even in the time of Columella, agriculture and horticulture were as teachable as any other subject of the period, but, because the luxury loving landlords saw fit to abrogate their responsibilities and to delegate the tilling of the soil to their less intelligent servants, agriculture became a sordid occupation and man saw little in it but sweat and toil. He lost sight of the great cycle of life of which the soil is the basis; and there

came to pass that condition of affairs so greatly feared by our wise philosopher: that is agriculture had indeed become a sordid occupation, and now nearly 2,000 years later, there are still living among us those who do not yet realize that of the words agriculture and horticulture more than half are "culture."

History is of little value except in helping one predict the future. It took men almost twenty centuries to grasp some realization of the importance of agriculture, and it has taken the greatest economic crisis in the history of our world's civilization to crystallize that realization. I sometimes wonder if the phrase that we have heard so often repeated during the past twenty years concerning the "drudgery in the home" is the fore-runner of a system of thought that will cause the abrogation of responsibilities and fetter man for another 2,000 years or more.

Somehow that portion of agriculture dealing with fruits, vegetables and flowers, namely horticulture, did not, in the minds of men, sink to the same level with ordinary farming. Possibly the horticulturists were the fore-runners of the "pure scientists", for it is certain that in the early days a large portion of the products of their toil were of little practical and economic value. They could not be shipped, nor could they be kept; they influenced life merely in a transient way, being produced for the pleasure and enjoyment the plants, themselves, afforded rather than in anticipation of any monetary reward. Under such conditions, horticulture could fortunately become the pursuit of a gentleman; for it has long been recognized that a gentleman could put forth effort, energy and sweat besides soiling his hands in the production of a rose or the riding of a horse; but if he drove the same horse and expended the same amount of effort, energy and sweat in the growing of a field crop, he became a plebian, an individual to be looked down upon.

Horticulture was an amateur calling from the days of Columella to the middle of the nineteenth century; and even yet amateurs are occasionally found among apple and pear trees, or in gardens near cabbages and carrots, sometimes on lawns near clumps of shrubs or beds of flowers from whence they peep out upon the world with bright and shining eyes filled with happiness and contentment, their voices mellowed with the love of nature and the philosophy of living. It is a pity that the age of "internal combustion" has so beset them with "ologies" that they have practically disappeared, and unless the few remaining are carefully protected, this species will soon be counted with things historic.

This benign type of individual was so common during the middle of the nineteenth century as to deserve the name "vulgaris". Ever since the days of Rome they had been on the increase; receiving something of a set-back during the "Dark Ages", but after that period of depression they emerged from the monasteries and rapidly increased in number, laying the basis for the establishment of schools and trades in Europe and the development of such aggre-

gations of congenial souls as the American Pomological Society in this country.

These early amateurs were building the foundation of our profession and producing cyclopedic writings and rule books of culture in large numbers; so also were their close associates, the general farmers, laying the bed rocks from which were to spring much of our present day agriculture.

Let us view for a moment the situation in this country about the middle of the nineteenth century. At the end of the seventeen hundreds this nation was mainly rural and producing just about enough for its needs, exporting some tobacco, cotton and rice. Horticultural products were all home grown and had only a very limited local market. Following the invention of the cotton gin, the opening of canals, the development of the railroads and the disruption of world economic conditions through the Napoleonic wars and our own War of 1812, commerce and industry developed. Thus we find the East industrialized, the South agricultural and the free lands of the West rapidly developing into a great grain and animal section. Agriculture had gone through the stage of home consumption and the horticulturists were catching glimpses of extensive orchards and gardens in the future. Protective tariffs had been passed and the conflict between agriculture and industry had already brought on the Civil War, and the same conflict may, in the near future, bring some other great cataclysm to this nation.

Such conditions brought rural problems to the forefront in the minds of thinking men; mayhap they sensed the great industrial-agricultural conflict that was on and caught a glimpse of its future magnitude. Be that as it may, the Congress of the United States, in the midst of national strife, legislated into being a system of education that, through the Land Grant institutions, would pay its dividends during the time of peace. Thus after eighteen hundred years was the lamentation of Columella fully answered, there were to be scholars and teachers of agriculture.

If 1870 is accepted as the approximate date at which these institutions really began to function, it is only fair that some estimate be made of what horticulture was at that time. Though there had been efforts at instruction in this subject in Europe and a few in America, the handling of it had been along apprenticeship lines: the teaching of a trade by rule of thumb, based upon a literature consisting of calendars and catalogues of varieties, Professional horticulturists, if we might call them that, were really managers of estates, or florists and gardeners about large centers of population. There were many amateurs and some several nurserymen also interested in the subject purely as home projects.

When one realizes that at the time of the passage of the Morrell Act botany and zoology were still in the systematic stage; bacteriology had not yet been born; genetics was still philosophy; and organic chemistry, though a lusty infant clamoring for recognition, had made little impression in learned circles; that physics had

progressed mechanically, but the realms of heat, light and electricity largely remained unexplored; that the bio-chemist, the bio-physicist, the soil scientist, the phytopathologist, the entomologist and many others had not yet come into being; it is easy then to understand the attitude of the academic mind when horticulture and other allied agricultural subjects were raised to the dignity of a college curriculum. Such subjects were not teachable in universities as they were not based on well organized information and backed up by a literature centuries old—besides they were merely trades and had no right to academic standing.

In the main this was largely true and was reflected in the organization of institutions with standards considerably below those set by the humanities. In the older states, already supplied with higher education, these new colleges were established separately; in others, they were connected with the budding university, and in still others they were destined to be the hub around which great institutions were to develop. In the beginning, they all had the ideal of preparing artisans in horticulture. The students were to go back to their orchards and gardens, increasing their production and bettering the living conditions throughout America. It was natural that such ideals should prevail as there were really no well established, well understood horticultural facts; science had not, as yet, removed our profession from the realm of astronomy.

Things did not happen, however, as anticipated; departments rapidly expanded and demanded these trained artisans as teachers, and gradually there developed a different ideal of horticulture. The period of 1870–1890 was one of great activity in our field. The constant search for well established facts and their organization into a body of teachable matter developed above all else the great fact that little was known. So noisy was the clamor for definite information and its dearth so apparent, not only in horticulture, but along all agricultural lines, that the Hatch Act found its way through the hoppers of Congress and gave us a new ideal of what a horticulturist could be.

Between 1890 and 1910, many more things happened to change our ideas of horticulture. The public still expected the product of the college to be an artisan, while the colleges themselves, the experiment stations and the rapidly expanding national Department of Agriculture recognized the demand for experimenters, teachers and scientists. The amateur was rapidly disappearing. There was, of course, still a lot of interest in the production of quality fruit about the homes, but the development of refrigeration and the railroads, into what we then considered rapid transportation, reorganized our industry. Extensive orchards spread themselves throughout California and the South; the vast vegetable fields of Texas and of Florida had begun to pour their out-of-season products upon the markets of the East. The experiment stations had amassed an enormous number of facts and the inquiring minds

of the profession were asking questions that were vitally more fundamental than the date of planting or pruning. The sciences had taken hold of horticultural problems. Pasteur, Koch and others had conjured bacteriology into being. The problems of evolution had become things of every-day discussion. Botany had slipped from its classification era into embryology, physiology and more basic discussions. At the beginning of the century the work of Mendel had been resurrected from dusty archives, and horticulture was launched into its economic and scientific being.

In academic centers science was fighting the humanities for its place in the sun, and it was during this era that there came into being that new species called the "pure scientist", unsullied and untouched by practicality, but willing enough to use the public monies, appropriated so that science could render more productive and remunerative the basic industries of the nation. It is well to remember that the scientists who have written their names across the pages of history have been those who have advanced mankind and relieved humanity of its burdens. They are honored in direct ratio to the advancement civilization has received from their discoveries. All science is pure: it matters not whether it is digging into the sewers of a great city or studying the elusive perfume of a spotless lily.

During this period, the Adams Act came into being. We then found ourselves launched upon definite scientific studies, and, if we look back upon this time, those of us who were in it can well remember the trials and troubles we had in organizing experimental work upon a scientific basis. To my mind the passage of the Adams Act was one of the most beneficial things that has happened to the profession of horticulture as a whole. It in reality showed us how little we knew about science, how unscientific we actually were. Up to that time we had been able to run out into the fields, plant a few seeds and set a few trees and then come in and tell our associates what a marvelous piece of scientific work we were conducting. But when we had to organize our thoughts and put them on paper and submit them to such men as then manned the Office of Experiment Stations, there were many of us who were not so certain about our scientific attainments; and, fortunately for us, those critics in Washington did not mince matters, consequently they had a great hand in the training of the men who were to come later.

This act again changed our ideal of a horticulturist. The experimenter had become a scientist even more than a fruit grower, and for a while we laid away the idea of simple demonstrations, but this was not long for it was realized that valuable information was not getting back to the farms where it could be profitably used and the Smith-Lever Act was the result.

This was rapidly followed by the Smith-Hughes Bill: a response to a demand for farmers and fruit growers on the soil which it was finally seen could not be met by the colleges, as estimates show that a large rural state requires in round numbers 4,000 new farmers

annually. These acts brought into being other species of horticulturists, namely, men with scientific training and practical ability who could teach in secondary schools or by demonstration in the rural districts and thus get back to the country information that it really needed. Also during this period of 1910-1920 the commercial horticulturist came to the forefront. He was found with railroads, spray companies, fertilizer companies, machinery companies, marketing organizations and the like.

Since 1920 specialization has increased and with the passage of the Purnell Act the economist has become important, injecting into our already complex organization other demands. Industry, in its selfishness and under artificial stimulation, had turned the United States from a rural into an urban nation, and the great industrial-agricultural conflict had practically throttled farming in its various forms before a realization was attained that the power, wealth and balance of trade of this country were in reality dependent upon the products of its soil and the labor of its rural population, which had for decades been producing against an impenetrable barrier of protection, for other interests, and forced to sell in open competition on the markets of the world. Is there any wonder that since 1920 the economical production and handling of our horticultural products have become prominent in our thoughts. The horticulturist can look with pride upon the fact that of the brotherhood of agricultural subjects his was the first to realize the importance of coordinating individual effort in projecting better methods of handling farm commodities; and, out of this experience of more than a quarter of a century, there should come to him the realization that he is better able to maintain himself under stress of modern conditions than other members of the rural fraternity; even though his advice has neither been sought nor listened to in the formulation of schemes and the passage of legislation intended to control the immutable laws of economics. It is a great pity, my friends, that money is not endowed with brains as well as power.

Today our institutions of learning are confronted with the necessity of preparing six types of horticulturists along several special lines, namely: artisans, extension workers, secondary teachers, economists for commercial positions, university and college teachers and investigators. The desire and necessity for the artisan is still with us and really the development of these men is essential to the well-being and public support of our profession. It is time that more fruit growers and gardeners were finding employment in the rural districts; and, until this comes about, it cannot be said that horticultural training has reached its fulfilment.

There is a demand for the extension man, an artisan understanding the scientific and economic fundamentals of his subject and able to demonstrate them. Such men must be leaders in their community, leading through the power of their intelligence, training and personality. Upon them is largely dependent the support given by the public to our profession. Closely allied to the extension man

is the teacher in secondary schools, who should be specially trained in the major farming interest of his immediate locality and be so well grounded in science that he can make its practical aspects understandable to young minds.

The field of business is rapidly demanding horticulturists. Either these men must be trained by our colleges or go through a hard school of experience after leaving us. Their education should be fundamentally broad so that they may fit into many situations, whether it be as an economist, a market specialist, or an adjunct to some manufacturing enterprise.

Our institutions must also train college and university teachers, men who should have a cultural and scientific background capable of giving them a broad understanding of the value of all learning and its intimate association with things horticultural. Unfortunately, in the past, many of us have been too one-sided and passed on to our classes prejudices that have not been conducive to developing a love of learning in all of its branches.

The capstone of our training arch should be scientists, investigators, men who are anxious and willing to spend their days in unraveling the secrets of nature in order that, through their efforts, the foundations of horticulture may be broadened and made more substantial so that the superstructure of profit can be enlarged and the welfare of humanity improved.

It is indeed foolish to suppose that any one course in horticulture can prepare men for all the above fields with the multi-various specializations possible within the fields themselves. Truly the "Division of Horticulture" should really be a college of the subject, and in one institution this condition has been approached. This is not the time to enter upon a "bone-dry" discussion of curricula, but it does appear to be the opportunity for bringing to your attention some major points upon which curricula in the future might be based.

The ever present demand for the artisan can well be met in the secondary schools as now organized, provided the universities properly train the teachers. From these high schools, there should be an ever-increasing stream of better trained men going back to the orchards and vegetable fields as well as into the nurseries and floral establishments of the country.

The leaders in extension and those interested in horticultural industries should certainly possess a collegiate degree, specialized during the last years along lines of particular interest to them. The same should be said of individuals desiring to become instructors in the high schools.

It is the training of the teacher for the university and college as well as the research worker that should demand our special attention; for in them lie the progress and well-being of our profession. The professors must prepare those who are to be teachers of artisans, therefore, they must be artisans themselves; likewise they must have a broad understanding of science and culture in general.

so as to be able to connect their subjects with others, something which has been woefully lacking in the past. To my mind, the best preparation for a teacher is found in a general scientific degree with four years or more of work in horticulture and his summers spent in travel and practical horticultural work. As yet no institution has had the "intestinal fortitude" to make such demands. Personally, I should like to be associated with such an organization, if in no greater capacity than foreman of the grounds. Somehow I do not feel that this individual requires any vast amount of specialization—he should rather lean towards breadth.

The research worker, on the other hand, should be specialized to the nth power. He should probably follow the general horticultural course with the usual specialization and electives in his chosen field, and end with the Doctor of Philosophy as now offered, thus putting himself into a position to make fundamental investigations of horticultural problems that the teachers pass on to the artisans and professional leaders.

The question of whether the research worker should be a teacher or not is always with us. Personally, I do not care to mix the two. The investigator, if teaching at all, should have a small and selected group of students capable of assisting him in his work. His attention should be given solely to his problems and not scattered in the preparation of lectures largely unrelated to the matters he has in hand. The average investigator is not a good teacher of undergraduates particularly; he usually bores them to extinction. The real teacher requires a dynamic personality, should be gifted with the diction of a Bacon and capable of linking horticulture into the scientific and cultural life of the times. The reputation of being an uninteresting and dry subject is not deserved by horticulture. It is possible, however, that those adjectives apply to some of the teachers thereof.

With the multitude of educational aims that are, by circumstances, forced upon the various divisions of horticulture, it would appear that there should be some agency functioning in a defining capacity over the courses as offered throughout the United States. As the government has been most active in furnishing legislation and money for these courses, it would seem, at first thought, that it should furnish the definitions. Such, however, is not the case; states-rights and bureaucracy do not harmonize; political conditions change and any organization arrogating unto itself the right of defining and scientifically investigating the requirements for the training of these six groups of horticulturists should be a cross section of this vast nation and free from the whims of any political party. Such an organization I conceive the Society for Horticultural Science to be. Organized for the furtherance of horticultural investigations and for the better teaching and dissemination of horticultural truths, it is composed of men from all states, capable of knowing the needs of the profession throughout the land and having definite knowledge of the opportunities afforded everywhere

for obtaining training to fulfil these needs. Should this organization expand, as it seems possible that it will in the future, and extend its membership into the more technical fields of horticultural industry and manufacturing, it would then have a broader background from which to project its definitions.

Any attempt at comparisons of courses and institutions would be ridiculous; however, the setting up of minimum standards for acceptable and accreditable work would mean vast improvement. It would not hamper those who already are well supplied with time and equipment and it would help others to get them. The expense of maintaining a large horticultural division capable of making specialists in all fields is so enormous that but few institutions are able to encompass it. There is no reason why we should not look forward to a regional development, a development in which institutions can specialize along those lines most adapted to their sections, so that they may draw students from many states rather than from one and then do an excellent job of training, not attempting mediocre work in all fields. Specialization in sub-tropical horticulture belongs primarily to California and Florida. There would seem to be little use for such courses elsewhere. It is equally foolish for sister states to expend large sums in establishing courses in horticultural manufacturing when one in a region would be sufficient.

There has been ample evidence of the advantages to be had from defining minimum requirements for first class courses. The American Medical Association has conferred great benefits upon its profession and humanity at large by naming the requirements for a Class A Medical School. The American Bar Association has done the same for schools of law. The Carnegie Foundation did the same when it defined a college course and thereby established the entrance requirements for universities and institutions of higher learning. Is there any reason why this association, composed as it is of men from all sections of the United States, who are thoroughly conversant with all of the requirements and necessities of the profession, should not take upon themselves the definition of minimum requirements of equipment and standards necessary for training accredited horticulturists along the various lines now open in the profession?

With the development of correspondence courses, the junior college, and the new quarter system idea, the whole question of curricula is in a state of flux, and out of it there will come somewhere the agricultural college requiring, certainly, a junior college diploma for entrance and mayhap an institution demanding a baccalaureate degree as a basis upon which to build a doctorate along horticultural lines. The time is ripe for definitions and those interested should formulate them. Why should not the American Society for Horticultural Science make investigations in this field and expend some of its energy along this line?

Obituary

WALTER LEON CUTLER

Mr. Walter Leon Cutler of the Massachusetts Agricultural Experiment Station died at the Massachusetts General Hospital in Boston, Mass., on October 31, 1931, after an illness lasting about two months.

He was born at Springfield, Vermont, July 1, 1902. He graduated from the Springfield High School in 1920. In the fall of 1921 he entered the Massachusetts Agricultural College with the class of 1925. After completing the freshman year he changed to the Two Year course in practical agriculture, majoring in Pomology, and graduated with honors in 1923.

After his graduation Mr. Cutler managed the home farm for a short time and then went into commercial work. On February 1, 1925, he returned to the college as Laboratory Assistant in the Pomology Department of the Experiment Station. Later he became Technical Assistant in the same department and held this position until his death.

Mr. Cutler's ambition spurred him on to work diligently to make up for his lack of technical training. In addition to his regular duties he took numerous courses in botany and plant physiology in the college. At the time of his death he had several experimental projects under way on which he had hoped to report before the American Society for Horticultural Science.

Since Mr. Cutler had only recently joined this organization, he was known to few of its members outside of New England, but all who knew him liked and respected him. He made friends easily and retained them. He was industrious and ambitious in his work and loyal to both the institution and his friends. One of his most outstanding characteristics was his readiness to help anyone, anywhere, anytime, even at personal sacrifice. He certainly would have risen in the ranks of horticulture had he been spared.

JOHN S. BAILEY.



WALTER LEON CUTLER

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ALDRICH, W. W.	U. S. Dept. Agr., Washington, D. C.
ALLEN, F. W.	University Farm, Davis, Calif.
ALLEN, R. C.	Cornell University, Ithaca, N. Y.
ANDERSON, J. W. C.	University of Missouri, Columbia, Mo.
ANDERSON, O. G.	Purdue University, Lafayette, Ind.
ANTHONY, R. D.	Experiment Station, State College, Pa.
ASAMI, Y.	Tokyo Imperial Univ., Komaba near Tokyo, Japan.
AUCHTER, E. C.	U. S. Dept. Agr., Washington, D. C.
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INDEX

	Page		Page
Acidified and limed soils for floricultural crops.....	416	effect of nitrate on carbohydrates in.....	501
Age and position of plant, relation to fruit bud differentiation in Dunlap strawberry.....	216	light and pigment development in.....	49
of plant, effect on flower production and yield of strawberries in North Carolina....	206	Jonathan, effect of fertilizer on storage of.....	572
Air circulation in cold storage tests with McIntosh.....	568	soil moisture and spray relation to stomata and growth of....	543
Alcohol method of preservation of sweet potato for analysis.....	276	temperatures of.....	566
Aldrich, W. W., paper by.....	532	transpiration rate of.....	590
Allen, R. C., paper by.....	410	Artichoke, Jerusalem, apical dominance in tuber of.....	301
Allen, F. W., paper by.....	639	seed piece size and sprout formation of.....	291
Anatomical difference in pecans....	158	rest period of.....	297
Annual meeting, resume of 1931....	xi	Artificial light for forcing plants...	402
Annuals, growth and flower production under cloth.....	393	Ashley, T. E., paper by.....	28
Anthesis and pollination of Capsicums.....	309	Asparagus, correlation between size of crown and yield.....	308
Apical dominance in tuber of Jerusalem artichoke.....	301	length of cutting season of.....	309
Apogamic and clonal progenies, selection within.....	53	Baby lima beans, thresher injury to	366
Apogamy in citrus and mangifera....	57	Bags, paper, seed production of beets under.....	328
Apple breeding, statistical analysis of.....	93	Bartlett pears, shape of.....	627
bud sports, pollination in Washington.....	74	Beans, baby lima, thresher injury to.....	366
color and size, light intensity in developing.....	552	green lima, chemical and physical changes in storage.....	367
McIntosh, fruit setting of in New Hampshire.....	87	Beattie, J. H., and Thompson, R. C., paper by.....	270
pollination in Champlain Valley	78	Beaumont, J. H., and Gardner, M. E., paper by.....	164
moisture relation to stomata of..	547	and Schmidt, R., paper by.....	167
orchard cover crop costs.....	654	and Morrow, E. B., paper by...	206
samples in experimental plots....	619	and Weaver, J. G., paper by.....	285
shoots, carbohydrates and nitrogen in, influenced by soil management.....	519	and Williams, C. F., paper by...	34
trees, biometrical presentation of pruning data.....	613	Bees, device for pollen distribution by.....	85
fruit thinning effect on carbohydrate, fruit bud formation, and set of bloom.....	599	Beets, premature seedstalk formation in.....	323
growth comparison on seedling roots and own roots.....	475	self-sterility and fertility, under paper bags.....	328
in sod, nitrogen supply for....	526	pollination of.....	332
nitrogen intake and translocation in.....	532	Berry and seed size of cane fruits..	194
pruning young.....	610	breeding, chromosome behavior in.....	114
tissues, starch-splitting enzyme in.....	561	<i>Beta vulgaris</i> , pollination of.....	332
varieties, newer, pollination of..	71	Biometrical presentation of data on pruning apple trees.....	613
washer, homemade paddle....	655	Bitter pit in relation to maturity and ripening of Gravenstein apples.....	639
Apples, Gravenstein, maturity and ripening of, in relation to bitter pit.....	639	Black-end in pear orchards.....	634
		Black raspberry, effect of fertilizers on growth and fruit production of.....	176
		Borthwick, H. A., paper by.....	310
		Boswell, V. R., paper by.....	297

	Page		Page
and Jackson, A. M., paper by.....	375	Chandler, W. H., Hoagland, D. R., and Hibbard, P. L., paper by.....	556
Brase, K., and Tukey, H. B., paper by.....	460, 489	Cherry, sweet, pollination in Washington for 1931.....	67
Bregger, J. T., paper by.....	200	Cherry trees, effect of paraffining, pruning, and other storage treatments on growth of.....	489
Brierley, W. G., paper by.....	180, 182, 188	Cherry, W. F., paper by.....	176
Breeding, apple, statistical analysis of.....	93	Chroboczek, E., paper by.....	323
berry, chromosome behavior in fruit, recording data of.....	114, 97	Chromosome behavior in berry breeding.....	114
influence on season of maturity in cabbage.....	359	Chrysanthemum, photoperiodism.....	389
strawberry, best parents for.....	107	Chrysanthemums, day length reduced by cloth for early blooms.....	382
Vinifera grapes.....	125	Citrus and mangifera, apogamy in.....	57
Broad-leaf evergreens of South-eastern states.....	444	Clark, J. H., paper by.....	211
Bud sports, apple, pollination in Washington.....	74	Claypool, L. L., and Morris, O. M., paper by.....	253
Bulbs, onion, wounding, effect of on seed production.....	336	Claypool, L. L., and Overholser, E. L., paper by.....	15, 220
Burkholder, C. L., and Greene, L., paper by.....	473	Overley, F. L., and Overholser, E. L., paper by.....	67
Burrell, A. B., and King, Geo. E., paper by.....	85	Clonal and apogamic progenies, selection within.....	53
and Parker, R. G., paper by.....	78	Cloth for growth and flower production for annuals.....	393
By-laws and constitution.....	x	use in reducing day length for early chrysanthemums.....	382
changes in.....	xii	Cochran, G. W., paper by.....	257
Cabbage, inbreeding, influence on season of maturity.....	359	and Webster, J. E., paper by.....	236
Cabbage seed, growing.....	341	Codling moth, oil sprays for.....	663
Calma, V. C., and Richey, H. W., paper by.....	131	Colby, A. S., and Tucker, L. R., paper by.....	143
Cane fruits, seed and berry size.....	194	Cold storage tests with McIntosh.....	568
Canes of Latham raspberry, transpiration in.....	188	Coldframes, ultra-violet transmitting glasses for vegetables in.....	375
Capsicums, anthesis and pollination of.....	309	Color and size of apple, light intensity in developing.....	552
Carbohydrate and nitrogen in apple shoots as influenced by soil management.....	519	and thickness of onion scales.....	318
Carbohydrate and nitrogen metabolism in celery.....	317	of hydrangeas.....	410
Carbohydrates, fruit bud formation and set of bloom in apples as affected by fruit thinning.....	599	tomato, affected by process temperature.....	353
Carbohydrates in apples, effect of nitrate on.....	501	Coloring, citrus, recent developments in.....	45
Carnations, effect of steaming soil on yield.....	413	Committees and officers for 1932.....	ix
Carolus, R. L., paper by.....	367	Concord grape cuttings, growth of.....	131
Carrot seed germination.....	310	effect of fruiting on shoot growth of.....	137
Carrying and keeping qualities of strawberries, effect of fertilizer on.....	224	fertilizer and fruit production effect on maturity of.....	147
Celery, carbohydrate and nitrogen metabolism in.....	317	influence of pruning and thinning on quality of.....	144
Chadwick, L. C., paper by.....	455	pruning, effect on fruiting and growth of.....	143
Chadwick, L. C., and DeWerth, A. F., paper by.....	432	Conifers, rooting of.....	447
Champlain Valley, pollination of McIntosh apple in.....	78	Constitution and By-laws.....	x
		changes in.....	xii
		Correlation between size of crown and yield of asparagus.....	308

	Page		Page
Costs, cover crop for apple orchards	654	Elberta peaches, growth and stomatal behavior, effect of weather on	539
Cover crop costs for apple orchards	654	growth and yield, effect of nitrate upon	34
Cracking test for pecans	164	Electricity for heating soil for gladioli	398
Cross and self fertility of red raspberry	118	Elm, seeds, effect of temperature and desiccation during storage on	441
Cullinan, F. P., paper by	1	Embryo and endosperm development of pecans and walnuts	161
and Sullivan, J. T., paper by	519	Emsweller, S. L., and Tavernetti, J. R., paper by	398
Cultural factors in red raspberry production, survey method for	200	Endosperm and embryo development of pecans and walnuts	161
Cutler, W. L., obituary	676	Enzyme, starch-splitting, in apple tissues	561
Cutting methods and peony fertilizers	423	Erwin, A. T., paper by	309
season of asparagus	309	Esper, H. C., and Roof, L. R., paper by	452
Cuttings, Concord grape, growth of	131	Evergreens, broad-leaf, of South-eastern states	444
deciduous hardwood, rooting of	455	grafting	498
of hardy fruits, rooting of soft and hardwood	460	Evolution of horticulturist	667
propagation of ornamentals by softwood	452	Executive committee, report of	xii
rooting of conifer	447	Falkenberg, G. V., and Ruth, W. A., paper by	657
Darrow, G. M., paper by	231	Fall flowering of red raspberry	180
and Sherwood, H., paper by	194, 225	cross and self, of red raspberry	118
Davis, L. D., and Tufts, W. P., paper by	485, 634	Fertility and self-sterility of beets under paper bags	328
Day length of chrysanthemum	389	Fertilizer, and fruit production, effect on maturity of Concord grape	147
reduced by cloth for early blooms	382	Fertilizer, effect on firmness and flavor of Strawberries in North Carolina	231
Decker, S. W., paper by	413	effect on growth and fruit of black raspberry	176
and Weinard, F. F., paper by	416, 423	effect on handling quality and chemical analyses of strawberries and tomatoes	236
DeFrance, J. A., paper by	444	effect on quality, keeping, and carrying of strawberries	224
Degman, E. S., and Furr, J. S., paper by	547	effect on respiration and physical properties of strawberries	220
Delicious hybrids, winter injury in Desiccation and temperature effect during storage on germination of elm seeds	103, 441	effect on storage of Jonathan apples	572
DeWerth, A. F., and Chadwick, L. C., paper by	432	effect on yield, quality, and keeping quality of Irish potatoes	256
Dexter, S. T., paper by	380	effect on carbohydrates in apples	501
Differentiation, flower bud, in gladiolus	407	effect on growth of peach	28
fruit bud, in Dunlap strawberry	216	effect on peach fruiting	23
Distribution, pollen, by bees, device for	85	nitrate, effect of time and rate on growth and yield of Elberta peaches	34
Dominance, proximal in sweet potato	270	phosphorus residua in orchard soils	509
Dorsey, M. J., and McMunn, R. L., paper by	619		
Dowd, O. J., paper by	590		
Drought in West Virginia orchards in 1930	646		
Dunlap strawberry, fruit bud differentiation in	216		
Early blooms of chrysanthemums, day length reduced by cloth for	382		
Edgecombe, S. W., and Lantz, H. L., paper by	93		

	Page		Page
Fertilizers for ornamental trees . . .	432	Furr, J. S., and Degman, E. S., paper by	547
peony, and cutting methods . . .	423	Gardner, M. E., and Beaumont, J. H., paper by	164
translocation in apple trees following nitrate applications .	532	and Schmidt, R., paper by	167
Filinger, G. A., paper by	515	Georgia Belle peach, soil moisture and leaf relation to fruit of . .	6
Filling of pecans and walnuts, re- lation of endosperm and em- bryo development to	161	Germination of carrot seed	310
Finch, A. H., paper by	158	of elm seeds, temperature and desiccation effect during stor- age on	441
Firmness and flavor of strawberries in North Carolina, effect of fertilizer on	231	Gladioli, effect of heating soil with electricity	398
Fisher, D. F., Harley, C. P., and Masure, M. P., paper by	561	Glasses, ultra-violet transmitting, for vegetables in coldframes .	375
Flavor and firmness of strawberries in North Carolina, effect of fertilizer on	231	Gladiolus, flower bud differenti- ation in	407
Floricultural crop growth on limed and acidified soil	416	Gourley, J. H., and Smock, R. M., paper by	509
Flower bud, differentiation in gladiolus	407	Grafting evergreens	498
production and growth of an- nuals under cloth	393	Grape, Concord, effect of fruiting on shoot growth of	137
and yield of strawberries in North Carolina, effect of age of plant on	206	cuttings, Concord, growth of . .	131
Flowering, fall, of red raspberry . .	180	fertilizer and fruit production effect on maturity of	147
Forcing plants with artificial light .	402	influence of pruning and thin- ning on quality of	144
Freezing method of preservation of sweet potato for analysis	276	pruning, effect on fruiting and growth of	143
preservation of fruits and vege- tables by	507	Grapes, irrigation experiments with	151
Fruit, breeding, recording data of .	97	Vinifera, breeding of	125
bud differentiation in Dunlap strawberry	216	Gravenstein apples, maturity and ripening of, in relation to bitter pit	639
formation, carbohydrates and set of bloom in apples as affected by fruit thinning . . .	599	Greene, L., and Burkholder, C. L., paper by	473
development period of straw- berries	211	Green lima beans, chemical and physical changes in storage . .	367
production, effect of thinning before June drop on	605	Greenhouse culture, sand as sub- stitute for soil in	427
and growth of black raspberry, effect of fertilizers on	176	Greve, E. W., and Hopkins, E. F., paper by	501
setting of McIntosh apple in New Hampshire	87	Griffiths, David, paper by	62
tomato, morphology affected by selection	350	Growth, and development of po- tato plant	279
Fruiting, and growth of tomato, effect of ringing on	343	and flower production of annuals under cloth	393
effect on shoot growth of Con- cord grape	137	and fruit of black raspberry, effect of fertilizers on	176
of peach, effect of nitrate of soda on	23	and fruiting of tomato, effect of ringing on	343
Fruits, and vegetables, effect of preservation by freezing on quality of	507	and stomata of Jonathan apples, soil moisture and spray re- lation to	543
propagation of soft and hard- wood cuttings of	460	and yield of Elberta peaches, effect of nitrate upon	34
vegetative propagation of de- ciduous	465	of floricultural crops on limed and acidified soils	416
		of peach, effect of nitrate of soda on	28

	Page		Page
Growth of peaches as affected by weather.....	539	Inbreeding, influence on season of maturity in cabbage.....	359
of pear inarches.....	485	Injury, thresher, to baby lima beans.....	366
of potato seedlings, effect of light and temperature on.....	285	Irrigation, effect on yield and quality of potatoes in Yakima Valley.....	249
of shade trees under lawn conditions.....	435	experiments with grapes.....	151
shoot, effect of Concord grape fruiting on.....	137	Italian prune, maturity of.....	578
studies of Latham raspberry.....	182	Jackson, A. M., and Boswell, V. R., paper by.....	375
Haber, E. S., paper by.....	308, 309	Jenkins, J. M., and Miller, J. C., paper by.....	315
Haller, M. H., Harding, P. L., Lutz, J. M., and Rose, D. H., paper by.....	583	Jerusalem artichoke, apical dominance in tuber of.....	301
Handling quality and chemical analyses of strawberries and tomatoes, effect of fertilizer on.....	236	rest period of.....	297
Hansen, C. J., and Tufts, W. P., paper by.....	627	seed piece size and sprout formation of.....	291
Hardiness, studies by Newton pressure method.....	380	Jonathan apples, effect of fertilizer on storage of.....	572
Harding, P. L., Haller, M. H., Lutz, J. M., and Rose, D. H., paper by.....	583	soil moisture and spray relation to stomata and growth of.....	543
Hardy, Max B., paper by.....	118, 122	Jones, Ivan D., paper by.....	6
Harley, C. P., Fisher, D. F., and Masure, M. P., paper by.....	561	June drop, effect of thinning before, on fruit production.....	605
Haut, I. A., Overley, F. L., and Overholser, E. L., paper by.....	543	Keeping and carrying, qualities of strawberries, effect of fertilizer on.....	224
Healing skinned potatoes, effect of various factors on.....	266	quality, yield, and quality of Irish potatoes, effect of fertilizer on.....	256
Heinicke, A. J., paper by.....	526	Kimbrough, W. D., paper by.....	224, 256
Heating soil with electricity for gladioli.....	398	King, Geo. E., and Burrell, A. B., paper by.....	85
Helianthus tuberosus, apical dominance in tuber of.....	301	Klein, Irwin, paper by.....	447
rest period of.....	297	Knott, J. E., paper by.....	318
Hendrickson, A. H., and Veihmeyer, F. J., paper by.....	151	Knowlton, H. E., paper by.....	71
Hibbard, P. L., Chandler, W. H., and Hoagland, D. R., paper by.....	556	Lagasse, F. S., paper by.....	475
Hoagland, D. R., Chandler, W. H., and Hibbard, P. L., paper by.....	556	Lantz, H. L., paper by.....	97
Hofmann, Fred W., paper by.....	613, 654, 655	and Edgecombe, S. W., paper by.....	93
Hopkins, E. F., and Greve, E. W., paper by.....	501	and Nichols, H. E., paper by.....	103
Horticulturist, evolution of.....	667	Latham raspberry, growth studies of.....	182
Howard, W. L., paper by.....	465	transpiration in canes of.....	188
Howlett, F. S., paper by.....	605	Latimer, L. P., paper by.....	87
Humidity and temperature, effects on wetting peach shoots.....	657	Laurie, A., paper by.....	427
effect on healing skinned potatoes.....	266	Lawn, growth of shade trees in.....	435
relation to sun-scald of potatoes.....	261	Leaf, and soil moisture relation to fruit of Georgia Belle peach.....	6
Hybridity in Lilium.....	62	area, relation to peach size and quality.....	18
Hybrids, Delicious, winter injury in.....	103	peach, relation to physical properties and chemical compositions of.....	15
Hydrangeas, factors influencing color.....	410	Leguminous and non-leguminous sod, nitrogen for young apple trees in.....	526
Inarches, pear, growth of.....	485	Library, recommendations of committee regarding.....	xii
		Light and pigment development in apples.....	49

	Page		Page
and temperature, effect on growth and tuberization of potato seedlings	285	Morphology of tomato fruit, affected by selection	350
artificial, for forcing plants . . .	402	Morris, O. M., and Claypool, L. L., paper by	249, 253
intensity in development of apple color and size	552	Morrow, E. B., and Beaumont, J. H., paper by	206
Lilium, hybridity in	62	Mulch, paper, results with vegetable crops	305
Lima beans, baby, thresher injury to green, chemical and physical changes in storage	366	Newer apple varieties, pollination of	71
Limed and acidified soils for floricultural crops	416	New Hampshire, fruit setting of McIntosh apple in	87
Little-leaf or rosette in fruit trees	556	Newton pressure method, for studying hardness	380
Lettuce, respiration studies with . .	244	Nichols, H. E., and Lantz, H. L., paper by	103
Lott, Richard V., paper by	23	Nitrate, effect on carbohydrates in apples	501
Louisiana, strawberry culture in . .	173	effect on peach fruiting	23
Lutz, J. M., Haller, M. H., Harding, P. L., and Rose, D. H., paper by	583	fertilizer, effect of time and rate on growth and yield of Elberta peaches	34
and Winston, J. R., paper by . . .	45	nitrogen intake and translocation in apple trees following application of	532
MacGillivray, J. H., paper by . . .	353	of soda, effect on growth of peach	28
and Stair, E. C., paper by	350	sampling orchard soils for	515
McHatton, T. H., paper by	667	and carbohydrate metabolism in celery	317
McIntosh apple, pollination in Champlain Valley	78	Nitrogen and carbohydrates in apple shoots as influenced by soil management	519
fruit setting in New Hampshire . .	87	concentration variation in peach twigs	39
cold storage tests with	568	for young apple trees in sod . . .	526
McKenzie, K. A., paper by	244	intake and translocation in apple trees from nitrate applications	532
McMunn, R. L., and Dorsey, M. J., paper by	619	North Carolina, effect of age of plant on flower production and yield of strawberries in . .	206
Magruder, R., paper by	328, 332	fertilizer, effect on firmness and flavor of strawberries	231
Mahaleb seedlings, size influence on nursery grades	473	pecan performance records in . .	167
Maney, T. J., paper by	496	Nursery stock, effect of paraffining, pruning, and other storage treatments on growth of . .	489
Magnifera and citrus, importance of apogamy in	57	Nutrients for ornamental trees . .	432
Marth, P. C., and Schrader, A. L., paper by	552	Obituary notice	676
Masure, M. P., Harley, C. P., and Fisher, D. F., paper by	561	Officers and committees for 1932 . .	ix
Maturity, and ripening of Gravenstein apples in relation to bitterpit	639	election of	xi
in cabbage, influence of inbreeding on	359	Oil sprays for codling moth	663
of Concord grape, effect of fertilizer and fruit production on .	147	Oklahoma, seed for late potatoes in	257
of Italian prune	578	Onion bulbs, wounding effect on seed production	336
Membership roll for 1931	677	scales, color and thickness of . .	318
Metabolism, nitrogen, and carbohydrate in celery	317	Ornamental trees, nutrients for . .	432
Meyer, A., paper by	566	Ornamentals, propagation of softwood cuttings of	452
Miller, J. C., paper by	341		
and Jenkins, J. M., paper by . . .	315		
Moisture relation to stomata of apple	547		
relation to stomata and growth of Jonathan apples	543		
soil, relation to fruit of Georgia Belle peach	6		
Morgan, N. D., paper by	276		

	Page		Page
Overholser, E. L., and Claypool, L. L., paper by.....	15, 220	Peony fertilizers and cutting methods.....	423
and Overley, F. L., paper by.....	67	Phloxes, summer flowering.....	418
	74, 572	Phosphorus residua in orchard soils.....	509
and Haut, I. A., paper by.....	543	Photoperiodism of chrysanthemum.....	389
Overley, F. L., and Overholser, E. L., paper by.....	74, 572	Pigment and light development in apples.....	49
and Haut, I. A., paper by.....	543	Platenius, H., paper by.....	317
Claypool, L. L., and Overholser, E. L., paper by.....	67	and Thompson, H. C., paper by.....	305
Paper bags, seed production of beets under.....	328	Poesch, G. H., paper by.....	389, 402
mulch, results with vegetable crops.....	305	Pollen, device for distribution of.....	85
Paraffin and waxes, apparatus for spraying.....	496	Pollination and anthesis of Capsicums.....	309
storage treatment, effect on growth of roses and cherry trees.....	489	of apple bud sports in Washington.....	74
Parker, R. G., and Burrell, A. B., paper by.....	78	of beets.....	332
Partridge, N. L., paper by.....	144, 147	of McIntosh apple in Champlain Valley.....	78
Peach fruiting, effect of nitrate of soda on.....	23	of newer apple varieties.....	71
Georgia Belle, soil moisture and leaf relation to fruit of.....	6	of sweet cherry, in Washington for 1931.....	67
growth, effect of nitrate of soda on.....	28	technique, red raspberry.....	122
leaf, area in relation to physical properties and chemical composition of.....	15	Post, K., paper by.....	382, 393
leaf area in relation to size and quality.....	18	Potato plant, growth and development of.....	279
shoots, effect of humidity and temperature on wetting of.....	657	plants, effect of spacing and thinning.....	253
tree response and internal composition of.....	1	seedlings, effect of temperature and light on growth and tuberization of.....	285
twigs, nitrogen concentration variation in.....	39	sweet, proximal dominance.....	270
Peaches, effect of weather upon growth and stomatal behavior of.....	539	Potatoes, fertilizer, effect on yield, quality, and keeping quality of.....	256
Elberta, growth and yield, effect of nitrate upon.....	34	of Yakima Valley, effect of irrigation on yield and quality of.....	249
Peacock, W. M., paper by.....	266	seed, for late crop of in Oklahoma.....	257
Wright, R. C., and Whiteman, T. M., paper by.....	261	skinned, effect of various factors on healing of.....	266
Pear inarches, growth of.....	485	sun-scald, relation of solar and sky radiation, temperature, and humidity to.....	261
orchards, black-end in.....	634	Preservation by freezing on quality of fruits and vegetables.....	507
Pears, Bartlett, shape of.....	627	of sweet potato for sugar determination.....	276
Pearce, G. W., and Streeter, L. R., paper by.....	49	Pressure, Newton method, for studying hardness.....	380
Pearson, O. H., paper by.....	359	Pridham, A. M. S., paper by.....	418
Pecan, cracking tests of.....	164	Processing temperature, effect on tomato color.....	353
anatomical differences in.....	158	Propagation of hardy fruits by soft and hardwood cuttings.....	460
and walnuts, relation of endosperm and embryo development to filling of.....	161	of softwood cuttings of ornamentals.....	452
performance records in North Carolina.....	167	vegetative, of deciduous fruits.....	465
		Prune, Italian, maturity of.....	578
		Pruning and thinning, influence on quality of Concord grape.....	144
		biometrical presentation of data with apple trees.....	613

	Page		Page
effect on fruiting and growth of		Rooting of conifers	447
Concord grape	143	of deciduous hardwood cuttings .	455
storage treatment, effect on		of soft and hardwood cuttings of	
growth of roses and cherry		hardy fruits	460
trees	489	Roots, seedling and own, compari-	
young apple trees	610	son apple tree growth on . . .	475
<i>Prunus Tomentosa</i> , self - unfruit-		Rose, D. H., Haller, M. H., Harl-	
fulness in	112	ing, P. L., and Lutz, J. M.,	
Quality and size of peach in re-		paper by	583
lation to leaf area	18	Roses, effect of paraffining, prun-	
and yield of potatoes in Yakima		ing, and other storage treat-	
Valley, effect of irrigation on .	249	ments on growth of	489
of Concord grape, influence of		Rosette or little-leaf in fruit trees .	556
pruning and thinning on . . .	144	Ruth, W. A., and Falkenberg,	
of fruits and vegetables, effect of		G. V., paper by	657
preservation by freezing on .	507	Sampling apples in experimental	
keeping, and carrying of straw-		plots	619
berries, effect of fertilizer on .	224	orchard soils for nitrate	515
yield, and keeping quality of		Sand as substitute for soil in green-	
Irish potatoes, effect of fertil-		house	427
izer on	256	Scales, onion, color and thickness	
Rainfall, standard	594	of	318
Rasmussen, E. J., paper by . . .	568	Schilleter, J. C., paper by	216
Raspberry, black, effect of fertil-		Schmidt, R., Beaumont, J. H., and	
izers on growth and fruit pro-		Gardner, M. E., paper by . . .	167
duction of	176	Schrader, A. L., paper by	137
Latham, growth studies of . . .	182	and Marth, P. C., paper by . . .	552
transpiration in canes of	188	Scion and stock relations	470
red, fall flowering of	180	Season of maturity in cabbage,	
pollination technique	122	influence of inbreeding on . . .	359
production, survey method for		Seed and berry size of cane fruits .	194
cultural factors in	200	cabbage, growing	341
self and cross fertility of	118	carrot, germination of	310
Rate and time of nitrate fertil-		piece, size and sprout formation	
ization, effect on growth and		of Jerusalem artichoke	291
yield of Elberta peaches	34	potatoes, for a late crop in Okla-	
Red raspberry, fall flowering of .	180	homa	257
pollination technique	122	production, effect of wounding	
production, survey method for		onion bulbs upon	336
cultural factors in	200	production of beets under paper	
self and cross fertility of	118	bags	328
Reproduction of shallots	315	Seeding of celery, carbohydrate	
Resolutions	xiii	and nitrogen in relation to . . .	317
Respiration and physical properties		Seedling roots and own roots, com-	
of strawberries, effect of fertil-		parison apple tree growth on .	475
izer on	220	Seedlings, Mahaleb, size, influence	
in relation to temperature of		on nursery grades	473
fruits	583	potato, effect of temperature	
studies with lettuce	244	and light on growth and tuber-	
Rest period of Jerusalem artichoke	297	ization of	285
Richey, H. W., and Calma, V. C.,		Seeds, American elm, effect of	
paper by	131	temperature and desiccation	
Ringling, effect on growth and		during storage on	441
fruiting of tomato	343	Seedstalk, premature formation in	
Ripening and maturity of Graven-		beets	323
stein apples in relation to		Selection, morphology of tomato	
bitter pit	639	fruit affected by	350
Roberts, R. H., paper by	470	within apogamic and clonal	
Roll, Membership for 1931	677	progenies	53
Roof, L. R., and Esper, H. C.,		Self and cross fertility of red rasp-	
paper by	452	berry	118

	Page		Page
sterility and fertility of beets under paper bags.....	328	Stair, E. C., and MacGillivray, J. H., paper by.....	350
unfruitfulness in <i>Prunus Tomen-</i> <i>tosa</i>	112	Standard rainfall.....	594
Set of bloom, formation of fruit buds, carbohydrates in apples as affected by fruit thinning..	599	Starch-splitting enzyme in apple tissues.....	561
Setting, fruit of McIntosh apple in New Hampshire.....	87	Statistical analysis of apple breed- ing.....	93
Shade trees, growth under lawn conditions.....	435	Steaming, soil, effect on yield of carnations.....	413
Shallots, reproduction of.....	315	Steinbauer, C. E., paper by.....	343
Shape of Bartlett pears.....	627	and Steinbauer, G. P., paper by.....	441
Sherwood, H., and Darrow, G. M., paper by.....	194, 225	Stock and scion relations.....	470
Shuhart, D. V., paper by.....	161	Stomata and growth of Jonathan apples, soil moisture and spray relation to.....	543
Size and color of apple, light in- tensity in developing.....	552	of apple, moisture, relation to... ..	547
and quality of peach in relation to leaf area.....	18	Stomatal behavior of peaches as affected by weather.....	539
Sky and solar radiation, effect on healing skinned potatoes... ..	266	Storage, of green lima beans, chemical and physical changes in.....	367
relation to sun-scald of potatoes.	261	of Jonathan apples, effects of fertilizer on.....	572
Slate, G. L., paper by.....	107, 112	temperature and desiccation on germination of elm seeds....	441
Smith, Ora, paper by.....	279	tests with McIntosh.....	568
Smock, R. M., and Gourley, J. H., paper by.....	509	treatments, effect on growth of roses and cherry trees.....	489
Snyder, Elmer, paper by.....	125	Stoutemyer, V. T., paper by.....	498
Sod, leguminous and non-legumi- nous, nitrogen for young apple trees in.....	526	Strawberry breeding, best parents for.....	107
Soil, heating with electricity for gladioli.....	398	culture in Louisiana.....	173
management influence on carbo- hydrates and nitrogen in apple shoots.....	519	Dunlap, fruit bud differenti- ation in.....	216
moisture and leaf relation to fruit of Georgia Belle peach... ..	6	Strawberries, and tomatoes, effect of fertilizer on handling qual- ities and chemical analyses... ..	236
relation to stomata and growth of Jonathan apples.....	543	effect of fertilizer on flavor and firmness of.....	231
sand as substitute for, in green- house.....	427	effect on respiration and physical properties of.....	220
steaming, effect on yield of carnations.....	413	fertilizer, effect on quality, keep- ing, and carrying of.....	224
Soils, orchard, residua of phos- phorus in.....	509	fruit development period of... ..	211
sampling for nitrate.....	515	in North Carolina, effect of age of plant on flower production and yield.....	206
Solar and sky radiation, effect on healing skinned potatoes....	266	transpiration of.....	225
relation to sun-scald of potatoes.	261	Streeter, L. R., and Pearce, G. W., paper by.....	49
Spacing and thinning, effect on potato plants.....	253	Sugar determination of sweet po- tato, method of preservation for.....	276
Sports, apple pollination in Wash- ington.....	74	Sullivan, J. T., and Cullinan, F. P., paper by.....	519
Spray, relation to stomata and growth of Jonathan apples... ..	543	Summer flowering phloxes.....	418
Spraying with paraffin and waxes, apparatus for.....	496	Sun-scald of potatoes, relation of solar and sky radiation, tem- perature, and humidity to... ..	261
Sprays, oil, for codling moth.....	663	Survey method for cultural factors in red raspberry production... ..	200
Sprout removal and sprout for- mation of Jerusalem artichoke	291	Swartwout, H. G., paper by.....	663

	Page		Page
Sweet cherry pollination in Washington for 1931.....	67	Transpiration in canes of Latham raspberry.....	188
Sweet potato, method of preservation, for analysis.....	276	of strawberries.....	225
proximal dominance in.....	270	rate of apples.....	590
Szymoniak, B., paper by.....	173	Treasurer's report for 1931.....	xiv
Tabor, P., paper by.....	594	Trees, ornamental, nutrients for.....	432
Talbert, T. J., paper by.....	610	shade, growth under lawn conditions.....	435
Tavernetti, J. R., and Emmsweller, S. L., paper by.....	398	Tuberization of potato seedlings, effect of light and temperature on.....	285
Technique, pollination, red raspberry.....	122	Tucker, L. R., paper by.....	578
Temperature and desiccation effect during storage on germination of elm seeds.....	441	and Colby, A. S., paper by.....	143
and humidity, effects on wetting peach shoots.....	657	Tufts, W. P., and Davis, L. D., paper by.....	485, 634
and light, effect on growth and tuberization of potato seedlings.....	285	and Hansen, C. J., paper by.....	627
effect, on healing of skinned potatoes.....	266	Tukey, H. B., and Brase, K., paper by.....	460, 489
in relation to respiration of fruits.....	583	Twigs, peach, nitrogen concentration variation in.....	39
processing, effect on tomato color.....	353	Ulmus americana seeds, effect of temperature and desiccation during storage on.....	441
relation to sun-scald of potatoes.....	261	Ultra-violet transmitting glasses for vegetables in coldframes.....	375
Temperatures of apples.....	566	Vegetable crops, results with paper mulch.....	305
Thickness and color of onion scales.....	318	Vegetables and fruits, effect of preservation by freezing on quality of.....	507
Time and rate of nitrate fertilization, effect on growth and yield of Elberta peaches.....	34	in coldframes, ultra-violet transmitting glasses for.....	375
Thinning and pruning, influence on quality of Concord grape.....	144	Vegetative propagation of deciduous fruits.....	465
and spacing, effect on potato plants.....	253	Veihmeyer, F. J., and Hendrickson, A. H., paper by.....	151
effect before June drop on fruit production.....	605	Verner, L., paper by.....	646
effect on carbohydrate, fruit bud formation, and set of bloom in apple trees.....	599	Vinifera grapes, breeding of.....	125
Thompson, H. C., and Platenius, H., paper by.....	305	Walnuts and pecans, relation of endosperm and embryo development to filling of.....	161
Thompson, R. C., and Beattie, J. H., paper by.....	270	Washer, apple, homemade paddle.....	655
Thresher injury to baby lima beans.....	366	Washington, pollination of apple bud sports in.....	74
Tomato color, affected by process temperature.....	353	sweet cherry pollination in.....	67
fruit, morphology affected by selection.....	350	Watkins, J. V., paper by.....	407
ringing, effect on growth and fruiting of.....	343	Waxes and paraffin, apparatus for spraying.....	496
Tomatoes and strawberries, effect of fertilizer on handling qualities and chemical analyses.....	236	Weather affect on growth and stomatal behavior of peaches.....	539
Translocation and nitrogen intake in apple trees from nitrate applications.....	532	Weaver, J. G., and Beaumont, J. H., paper by.....	285
Transmitting glasses, ultra-violet for vegetables in coldframes.....	375	Webber, H. J., paper by.....	53, 57
		Webster, J. E., and Cochran, G. W., paper by.....	236
		Weinard, F. F., and Decker, S. W., paper by.....	416, 423
		Weinberger, J. H., paper by.....	18, 539
		West Virginia, drought in orchards in 1931 in.....	640
		Wetting peach shoots, effect of humidity and temperature on.....	657

	Page		Page
Whiteman, T. M., Peacock, W. M., and Wright, R. C., paper by..	261	Yakima Valley, effect of irrigation on yield and quality of po- tatoes in.....	249
Williams, C. F., paper by.....	39	Yarnell, S. H., paper by.....	114
and Beaumont, J. H., paper by..	34	Yield and flower production of strawberries in North Caro- lina, effect of age of plant on..	206
Wilson, A. L., paper by.....	336	and growth of Elberta peaches, effect of nitrate upon.....	34
Winston, J. R., and Lutz, J. M., paper by.....	45	and quality of potatoes of Yaki- ma Valley, effect of irrigation on.....	249
Winter injury in Delicious hybrids.	103	asparagus, correlation between size of crown in.....	308
Woodroof, J. G., paper by.....	507	of carnations, effect of steaming soil on.....	413
Wounding onion bulbs, effect on seed production.....	336	quality, and keeping quality of Irish potatoes, effect of ferti- lizer on.....	256
Wounds of potatoes, effect of vari- ous factors on healing of....	266		
Wright, R. C., Peacock, W. M., and Whiteman, T. M., paper by.....	261		
Wyman, D., paper by.....	435		

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